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CONTRIBUTORS TO FOURTH EDITION

HENRY MORRIS, F.R.C.S., London.

R. J. TERRY, Washington University, St. Louis.

PETER THOMPSON, King's College, London.

IRVING HARDESTY, University of California.

G. CARL HUBER, University of Michigan.

J. PLAYFAIR McMURRICH, University of Toronto.

ABRAM T. KERR, Cornell University.

CHARLES R. BARDEEN, University of Wisconsin.

FLORENCE R. SABIN, Johns Hopkins University.

R. MARCUS GUNN, F.R.C.S., London.

W. H. A. JACOBSON, F.R.C.S., Guy's Hospital, London.

For arrangement of subjects and authors see page v.

MORRIS'S

HUMAN ANATOMY

A COMPLETE SYSTEMATIC TREATISE BY ENGLISH AND AMERICAN AUTHORS

EDITED BY

HENRY MORRIS, M.A. AND M.B. LOND., F.R.C.S. ENG.

PRESIDENT OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND; CONSULTING SURGEON TO MIDDLESEX HOSPITAL, LONDON; HONORARY MEMBER OF THE MEDICAL SOCIETY OF THE COUNTY OF NEW YORK; FORMERLY CHAIRMAN OF THE COURT OF EXAMINERS OF THE ROYAL COLLEGE OF SURGEONS; EXAMINER IN ANATOMY IN THE UNIVERSITY OF DURHAM, AND EXAMINER IN SURGERY IN THE UNIVERSITY OF LONDON

AND

J. PLAYFAIR MCMURRICH, A.M., PH.D.

PROFESSOR OF ANATOMY, UNIVERSITY OF TORONTO; FORMERLY PROFESSOR OF ANATOMY, UNIVERSITY OF MICHIGAN; MEMBER ASSOCIATION OF AMERICAN ANATOMISTS; MEMBER OF ADVISORY BOARD, WISTAR INSTITUTE OF ANATOMY, ETC.

TEN HUNDRED AND TWENTY-FIVE ILLUSTRATIONS
THREE HUNDRED AND NINETEEN PRINTED IN COLORS

FOURTH EDITION, REVISED AND ENLARGED

IN FIVE PARTS

PART III

THE NERVOUS SYSTEM. ORGANS OF SPECIAL SENSE

PHILADELPHIA
P. BLAKISTON'S SON & CO.
1012 WALNUT STREET
1907

WM. F. FELL COMPANY
Electrotypers and Printers
1220-24 Sansom Street
Philadelphia, Pa.

ARRANGEMENT OF SUBJECTS AND AUTHORS.

The names of those who originally wrote articles and those who revised and wrote for previous editions have been retained in the following list of contents, in order that due credit should be given them for the work done and for their share in the great success which Morris's "Anatomy" has achieved throughout England and America.

MORPHOGENESIS. (The Development of Structure.) By J. PLAYFAIR McMURRICH, A.M., PH.D., Professor of Anatomy, University of Toronto; Member Association of American Anatomists; Member of Advisory Board, Wistar Institute of Anatomy; Member of Editorial Board of "American Journal of Anatomy;" Author of "The Development of the Human Body."

OSTEOLOGY. Revised and largely rewritten for Third and Fourth Editions by PETER THOMPSON, M.D., Professor of Anatomy, King's College, London; Member of Anatomical Society of Great Britain. This article was originally written by J. Bland Sutton, F.R.C.S., formerly Examiner in Anatomy in Royal College of Surgeons.

ARTICULATIONS. By HENRY MORRIS, A.M. and M.B., London, President of the Royal College of Surgeons of England; Consulting Surgeon to, and formerly Lecturer on Surgery and Anatomy at, Middlesex Hospital, London; and Examiner in Anatomy, University of Durham, etc.

MUSCLES. Rewritten by CHARLES R. BARDEEN, A.B., M.D., Professor of Anatomy in the University of Wisconsin; Member Association of American Anatomists; Member of Editorial Board of "American Journal of Anatomy." Originally written by the late J. N. C. Davies-Colley, F.R.C.S., formerly Lecturer on Anatomy, Guy's Hospital, London.

HEART, BLOOD-VESSELS, AND LYMPHATICS. Revised and in part rewritten by FLORENCE R. SABIN, B.S., M.D., Associate Professor of Anatomy in the Johns Hopkins University; Member Association of American Anatomists. The section on Blood-vessels was originally written by the late William J. Walsham, F.R.C.S., formerly Lecturer on Anatomy, St. Bartholomew's Hospital, London. The section on the Heart in previous editions was written by the late Arthur Hensman, F.R.C.S., and revised by Arthur Robinson, M.D., Professor of Anatomy, University of Birmingham.

NERVOUS SYSTEM. Revised and largely rewritten by IRVING HARDESTY, A.B., PH.D., Assistant Professor of Anatomy, University of California; Member Association of American Anatomists. This section was originally written by the late H. St. John Brooks, M.D., formerly Chief Demonstrator of Anatomy, University of Dublin, and revised for the Second and Third Editions by Arthur Robinson, M.D., Professor of Anatomy, University of Birmingham.

ORGANS OF SPECIAL SENSE. Eye.—By R. Marcus Gunn, F.R.C.S., Senior Surgeon, Royal London Ophthalmic Hospital (Moorfields); Surgeon to the Western Ophthalmic Hospital and to the National Hospital for the Paralysed and Epileptic. Ear, Nose, Tongue.—By Abram T. Kerr, B.S., M.D., Professor of Anatomy, Cornell University; Member Association of American Anatomists. The sections on Ear, Nose, Tongue in previous editions were written by the late Arthur Hensman, F.R.C.S., and revised by Arthur Robinson, M.D., Professor of Anatomy, University of Birmingham.

ORGANS OF DIGESTION. Revised by G. Carl Huber, M.D., Professor of Histology and Embryology in the University of Michigan; Secretary Association of American Anatomists; Member of Advisory Board, Wistar Institute of Anatomy; Member of Editorial Board of "American Journal of Anatomy." This article was originally written by Sir Frederick Treves, K.C.V.O., F.R.C.S.

ORGANS OF VOICE, RESPIRATION, INCLUDING THE MEDIASTINA. By R. J. Terry, A.B., M.D., Professor of Anatomy, Washington University, St. Louis; Member Association of American Anatomists. These sections in previous editions were written by the late Arthur Hensman, F.R.C.S., and revised by Arthur Robinson, M.D., Professor of Anatomy, University of Birmingham.

URINARY AND GENERATIVE ORGANS. Revised by J. Playfair McMurrich, A.M., Ph.D., Professor of Anatomy, University of Toronto; Member Association of American Anatomists. This section includes "The Perineum," by Peter Thompson, M.D. These articles were originally written by the late William Anderson, F.R.C.S., formerly Vice-President Anatomical Society of Great Britain.

THE DUCTLESS GLANDS, INCLUDING THE THYREOID GLAND. By G. Carl Huber, M.D., Professor of Histology and Embryology in the University of Michigan; Secretary Association of American Anatomists.

THE SKIN AND MAMMARY GLAND. By Abram T. Kerr, B.S., M.D., Professor of Anatomy, Cornell University; Member Association of American Anatomists, etc. This article was originally written by the late William Anderson, F.R.C.S., formerly Vice-President Anatomical Society of Great Britain.

SURGICAL AND TOPOGRAPHICAL ANATOMY. By W. H. A. Jacobson, F.R.C.S., Consulting Surgeon to Guy's Hospital; formerly Lecturer on Anatomy, Guy's Hospital Medical School; Author of "The Operations of Surgery," etc.

ABSTRACT OF PUBLISHERS' NOTE

AS PRINTED IN PART I

The very favorable reception accorded the previous editions of this work in America suggested the desirability of making the present (fourth) edition international in its character, by placing it largely in the hands of an American editor and by securing the services of American Anatomists in the revision or rewriting of certain of the sections.

The entire work has undergone a complete revision, and some sections have been entirely rewritten and, in several instances, considerably enlarged; the text has been brought thoroughly up to date by the inclusion of the results of recent investigations, and represents, accurately, the present state of Anatomy. Many illustrations which appeared in previous editions have been omitted, a large number of new figures have been made from specially prepared drawings, and pictures from other books have been included where they served the desired purpose.

Special attention should be directed to the use throughout the volume of the nomenclature adopted by the German Anatomical Society and generally known as the Basle nomenclature, or BNA. In employing this nomenclature the editors have been guided by a desire to assist in the unification of anatomical terminology, seeing in such unification an earnest of the thorough internationalization of the science of anatomy and more rapid progress in its development. The modifications of the accepted English nomenclature necessitated by the adoption of the BNA are comparatively few, and where they are radical, the more familiar terms have been added in parentheses. Whilst this is the first text-book of Anatomy in English to adopt the BNA in its entirety, there are a number of books and papers on Embryology, Histology, and Biology in which it is used; its general adoption in the future, it may be confidently expected, will be assured. In this connection, reference should be made to a new book by Prof. Llewellys F. Barker, of Johns Hopkins University, in which a complete list of the terms used in the BNA is given and in which the object, system, and practicability of the nomenclature are explained.

Each author is alone responsible for the subject-matter of the article following his name. Care has been exercised on the part of the editors, however, to make the whole uniform, complete, and systematic.

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Revised and Largely Rewritten for the Fourth Edition by Irving Hardesty, A.B., Ph.D.

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PART II.—THE EAR, THE TONGUE, THE NOSE

ORIGINALLY WRITTEN BY ARTHUR HENSMAN, F.R.C.S.

REVISED AND LARGELY REWRITTEN FOR THE FOURTH EDITION BY ABRAM T. KERR, B.S., M.D.

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SECTION VI

THE NERVOUS SYSTEM

ORIGINALLY WRITTEN BY H. ST. JOHN BROOKS, M.D. REVISED FOR SECOND AND THIRD EDITIONS BY ARTHUR ROBINSON

REVISED AND LARGELY REWRITTEN FOR THE FOURTH EDITION

BY IRVING HARDESTY, A.B., PH.D.

ASSISTANT PROFESSOR OF ANATOMY, UNIVERSITY OF CALIFORNIA

THE nervous system of man, both anatomically and functionally, is the most highly developed and definitely distributed of all the systems of the body. It consists of an aggregation of peculiarly differentiated tissue-elements, so arranged that through them stimuli may be transmitted from and to all the other tissue systems. It is a mechanism with parts so adjusted that stimuli affecting one tissue may be conveyed, modified, and distributed to other tissues so that the appropriate reactions result. While protoplasm will react without nerves, while muscle will contract without the mediation of nerves, yet the nervous system is of the most vital importance to the higher organisms in that the stimuli required for the functioning of the organs are so distributed throughout their component elements that the necessary harmonious and coordinate activities are produced. For this purpose the nervous system permeates every organ of the body, the nerves dividing into smaller and smaller branches till the division attains the individual nerve-fibres of which the nerves are composed, and even the fibres bifurcate repeatedly before their final termination upon their allotted elements. So intimate and extensive is the distribution throughout that could all the other tissues of the body be dissolved away, still there would be left in gossamer its form and proportions—a phantom of the body composed entirely of nerves.

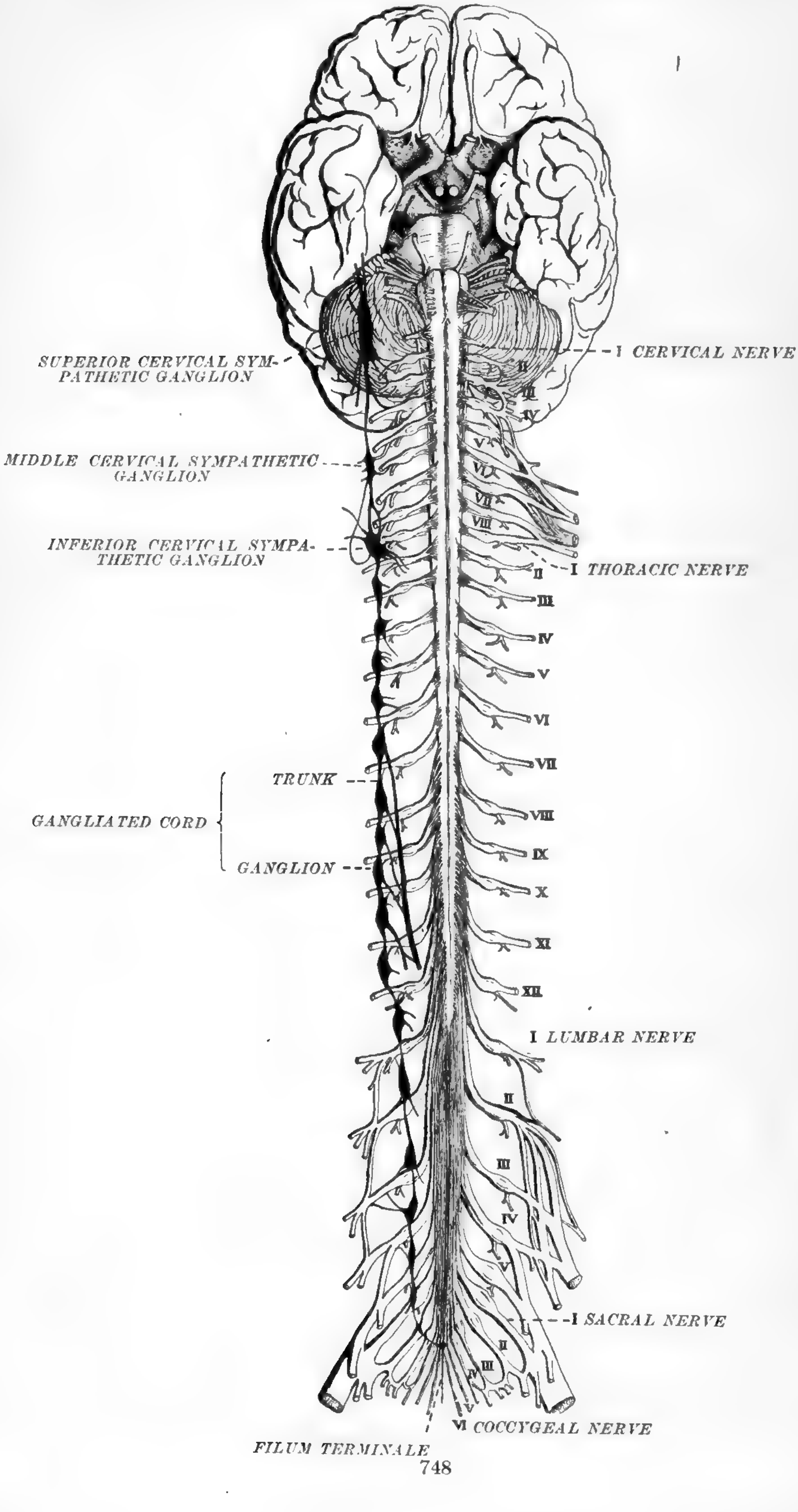
The parent portion or axis of the system extends along the dorsal mid-line of the body, surrounded by bone and, in addition, protected and supported by a series of especially constructed membranes or meninges, the outermost of which is the strongest. The cephalic end of the axis, the encephalon, is remarkably enlarged in man, and is enclosed within the largest portion of the bony cavity, the cranium, while the remainder of the central axis, the spinal cord, continues through the foramen magnum and lies in the spinal canal.

The intimate connection of the axis with all the parts of the body is attained by means of forty-three pairs of nerves, which are attached to the axis at somewhat regular intervals along its extent. They course from their segments of attachment through the meninges and through their respective foramina in the bony cavity to the periphery. Of these **cerebro-spinal nerves** twelve pairs are attached to the encephalon, and thirty-one pairs to the spinal cord. Most of them contain both **afferent fibres,** or fibres which convey impulses from the peripheral tissues to the axis, and **efferent fibres,** or fibres which convey impulses from the axis to the peripheral tissues. All the thirty-one pairs of spinal nerves possess fibres of both types, though in varying proportions.

Upon approaching the spinal cord, each spinal nerve is separated into two roots—its **dorsal root** and its **ventral root.** The afferent fibres enter the axis by way of the dorsal roots, which are, therefore, the sensory roots, and the efferent fibres leave the axis by way of the ventral or motor roots.

FIG. 554.—SHOWING THE VENTRAL ASPECT OF THE CENTRAL NERVOUS SYSTEM, WITH THE PROXIMAL PORTIONS OF THE CEREBRO-SPINAL NERVES ATTACHED AND THE RELATION OF THE PROXIMAL PORTION (GANGLIATED CORD) OF THE SYMPATHETIC NERVOUS SYSTEM. THE ENCEPHALON OR BRAIN IS STRAIGHTENED DORSALWARDS FROM ITS MORE HORIZONTAL POSITION WITH REFERENCE TO THE SPINAL CORD.

(Composite drawing in part after Allen Thompson from Rauber—modified.)



As usually studied, the nervous system is referred to in two main **divisions**:—

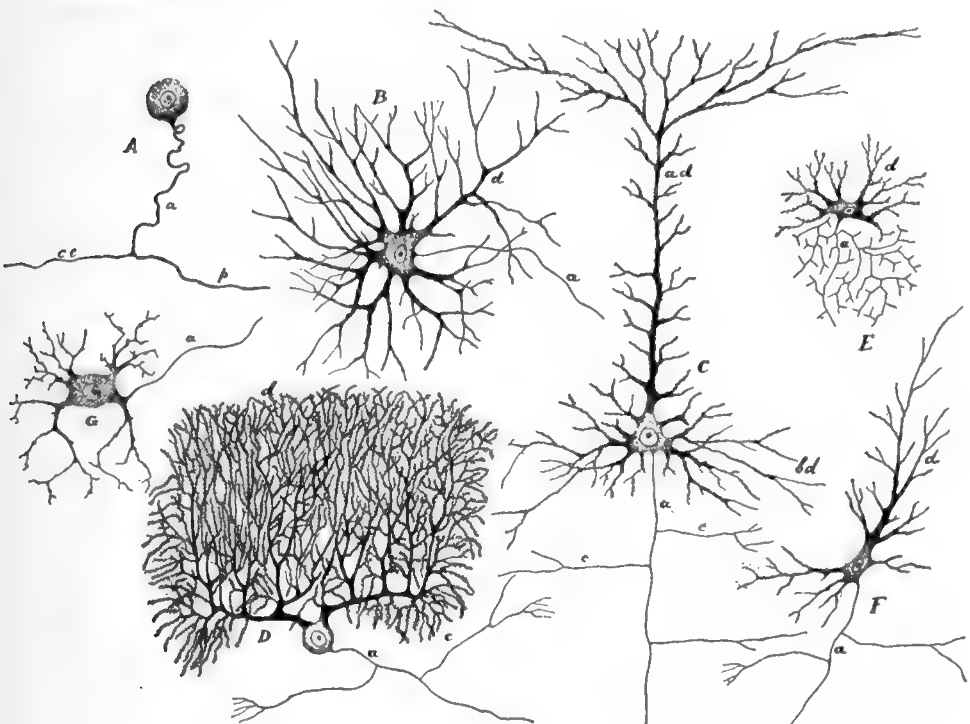
(1) The *central nervous system*, composed of—(*a*) The spinal cord, or medulla spinalis, and (*b*) the brain or encephalon.

(2) The *peripheral nervous system*, composed of—(*a*) The cerebro-spinal nerves, and (*b*) the sympathetic nervous system.

All these parts are so intimately connected with each other that the division is purely arbitrary. The cerebro-spinal nerves are anatomically continuous with the central system; their component fibres either arise within or terminate within the confines of the central system, and thus actually contribute to its bulk. The sympathetic system, however, may be more nearly considered as having a domain of its own. It is intimately associated with the cerebro-spinal nerves and thus with the central system, both receiving impulses from the central system and transmitting

Fig. 555.—Showing Some of the Varieties of the Cell-bodies of the Neurones of the Human Nervous System.

A. From spinal ganglion. *B*. From ventral horn of spinal cord. *C*. Pyramidal cell from cerebral cortex. *D*. Purkinje cell from cerebellar cortex. *E*. Golgi cell of type II from spinal cord. *E*. Fusiform cell from cerebral cortex. *G*. Sympathetic. *a*, axone; *d*, dendrites; *c*, collateral branches; *ad*, apical dendrites; *bd*, basal dendrites; *cc*, central process; *p*, peripheral process.



impulses which enter it, but, while its activities are largely under the control of the central system, it is possible that impulses may arise in the domain of the sympathetic system and, mediated by its nerves, produce reactions in the tissues it supplies without involving the central system at all. For this reason, as well as because of the structural peculiarities of the sympathetic system, the nervous system is sometimes divided into—(1) the cerebro-spinal system, consisting of (*a*) the central system and (*b*) the cerebro-spinal nerves; (2) the sympathetic nervous system, consisting of its various ganglia and plexuses.

The nervous system consists of its peculiarly differentiated cell-elements, held in place by two forms of supporting tissue and accompanied by an abundant supply of blood-vessels.

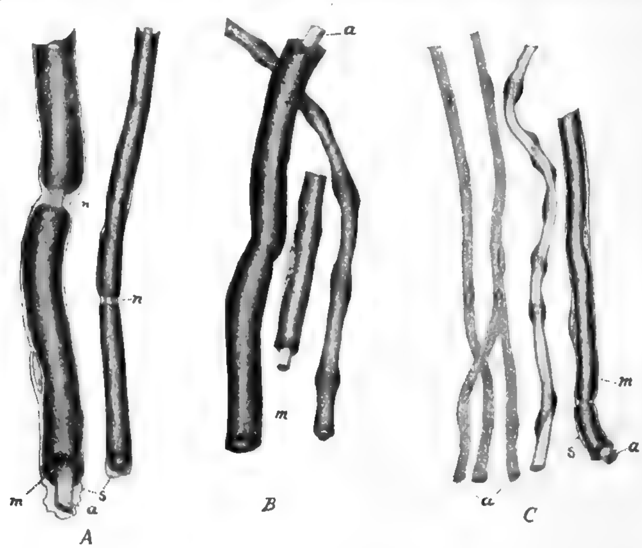
The nervous cell-element or the functional and structural unit of the system is called the **neurone**. The neurone is distinguished from all other units of structure

in the body in that it gives off outgrowths or processes of relatively great length and characteristic structure. The neurone may be defined as a **nerve-cell** with all its processes, however numerous and far-reaching. As a class of tissue-elements, all neurones possess characteristics which distinguish them from other tissue-elements, but within this class they vary greatly. They vary both according to function and according to their locality in the nervous system. Fig. 555 gives illustrations of the external form of a few of the types found in the human nervous system in the localities stated.

The cell-body of the neurone gives off two types of processes:—(1) The dendritic processes or **dendrites.** These serve to increase the absorbent surface of the cell-body for purposes of nutrition and also act as recipient surfaces for impulses transmitted to the neurone. They are, therefore, *cellipetal processes*. They branch at frequent intervals and always dichotomously and with rapid decrease in diameter. (2) The **axone** or neuraxis. Each neurone properly possesses but one of these. In most cases it is very much longer than any of the dendrites, and along its course it maintains a practically uniform diameter. Axones comprise the so-called axis-cylinders of all nerve-fibres, and thus they are the essential components

Fig. 556.—Showing Pieces of Axones.

A. From a cerebrospinal nerve. *B*. From the spinal cord. *C*. From the sympathetic. *a*, axones; *m*, medullary sheath; *n*, node of Ranvier; *s*, sheath of Schwann with occasional nuclei.



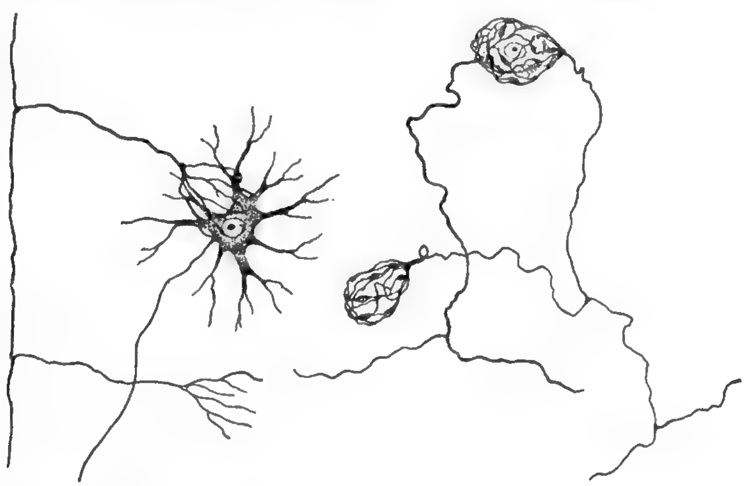
of all nerves and nerve fasciculi. Their usual nervous function is to convey impulses away from the cell-body of the neurone, either to other neurones in a chain or to appropriate elements of other tissue systems. Thus axones are *cellifugal processes*. They branch less frequently than dendrites, and in branching suffer almost no appreciable diminution in their diameter. Branches given off along the course of the axone are called **collaterals.** These are given off at right angles instead of dichotomously, thus differing from the form of branching of the dendrites. However, at its final termination the axone breaks up into numerous twigs and always dichotomously. The terminals of these twigs are known as **telodendria.** Though of minute diameter, the total bulk of the axone is relatively great. The longer of them—for example, those extending from the spinal cord for the innervation of the foot—may each comprise a volume more than two hundred times that of the cell-body giving origin to it.

The great majority of the axones of the nervous system acquire a protective and isolating envelope or sheath about them which begins a short distance from the parent cell-body and is lost only upon approaching the twigs of termination. In their study axones are divided according to the character of their sheaths. Those which possess in their sheaths that peculiar mixture of fats called myelin are **medullated**

axones, and those whose sheaths are void of myelin, **non-medullated axones.** However, there is no sharp line of separation between these two varieties, for there may be found axones with sheaths of all degrees of medullation. Most of the neurones with non-medullated and partially medullated axones belong to the sympathetic nervous system. Some sympathetic axones are completely medullated, but their myelin sheaths are always thinner and never so well developed as those of the cerebro-spinal nerves. Certain axones of short course in the central nervous system are non-medullated.

In internal structure the cell-body of the neurone consists of a large, spherical, vesicular nucleus with usually one characteristic, centrally placed nucleolus and a cytoplasm continuous into the axone and dendritic outgrowths. The two most interesting structures of the cytoplasm are its granular and fibrillar components. The granules are probably of nutritive significance, and, during the death changes in the cell, show a tendency to collect into clumps of characteristic shape and arrangement which are called **tigroid masses** or **Nissl bodies.** These masses are distributed throughout the cytoplasm with the interesting exception that they are not found in the axone or in the immediate vicinity of its hillock of origin. The protoplasmic fibrillæ, or spongioplasmic reticulum of the original cell, increase in

Fig. 557.—Schemes showing Two Forms of Termination of Axones upon Cell-bodies of other Neurones.
A. In ventral horn of spinal cord. B. In spinal ganglia.



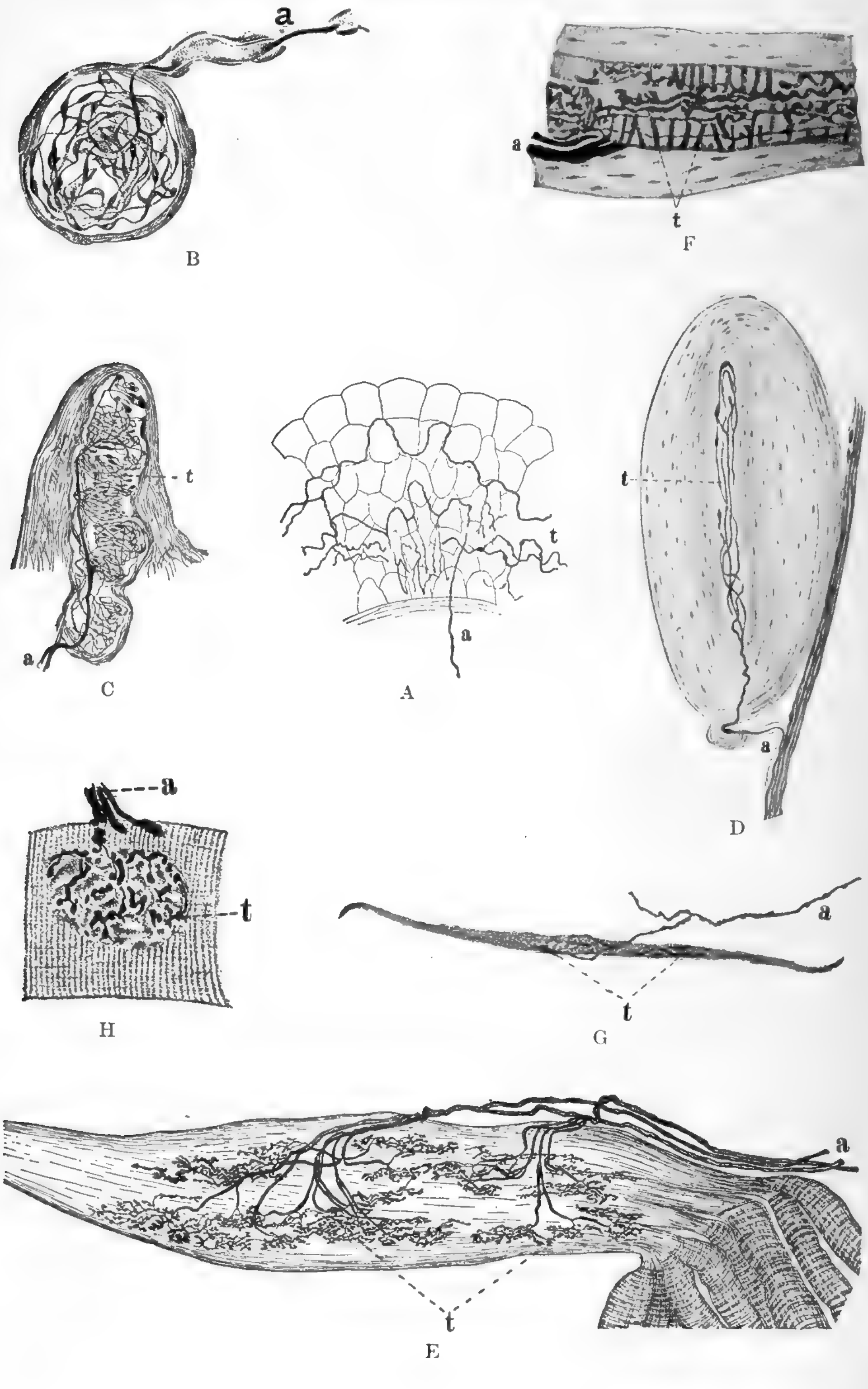
thickness during the development of the neurone, and in the sending out of the processes the meshes of the net become so drawn out as to give the appearance of a more or less parallel arrangement of the threads. This appearance sometimes becomes so manifest in the axone and portions of the cell-body that it has been interpreted as a series of individual and independent threads or **neuro-fibrillæ.**

Nerve impulses are transmitted from one element to another by means of contact rather than by direct anatomical continuity of the two. The axone bearing the impulse on approaching its termination loses its sheath and breaks up into its numerous terminal twigs, the final of which are called **telodendria.** Their terminal arrangement assumes forms varying from more compact 'pericellular baskets' to more open arborisations composed of fewer twigs. The twigs of the arborisation or **end-brush** are either clasped upon the dendrites of the neurone or upon its cell-body direct, as the case may be. The general manner of the contact is illustrated in fig 557. It should be mentioned that, contrary to the current belief that impulses are transmitted by simple contact of neurones, it has been advanced that the terminal twigs frequently penetrate the substance of the cell-body, and it has been held (more recently by Joris) that neuro-fibrillæ sometimes pass from one neurone into another.

The forms of nerve termination in the other tissues of the body are many and

FIG. 558.—SHOWING SOME VARIETIES OF PERIPHERAL TERMINATIONS OF AXONES.

A. 'Free termination' in epithelium (after Retzius). B. Krause's corpuscle from conjunctiva (after Dogiel). C. Meissner's corpuscle from skin (after Dogiel). D. Pacinian corpuscle (after Dogiel). E. Termination upon tendon (Huber and DeWitt). F. Neuro-muscular spindle (after Ruffini). G. Motor termination upon smooth muscle-cell. H. Motor 'end-plate' on striated muscle-cell (after Böhm and von Davidoff). a, axone; t, telodendria.



various. Functionally, they are necessarily of two classes, motor and sensory. Efferent fibres terminate chiefly upon muscle-cells forming the so-called **end-plates.** The forms of termination in which nerve impulses originate, those of the sensory or afferent fibres, vary from the simple or **free termination** of the telodendria upon the surfaces of epithelial cells to the most elaborate and complicated forms of the so-called **end-organs** or corpuscles. If medullated, the axone always loses its myelin sheath upon approaching its termination, and necessarily the terminal twigs are bare.

The supporting and **connective tissue** of the nervous system is of two main varieties—white fibrous connective tissue and **neuroglia.** White fibrous tissue alone supports and binds together the peripheral system, and it is the chief supporting tissue of the central system. As connective tissues, these two varieties are quite similar in structure, each consisting of fine fibrillæ, either dispersed or in bundles, among which are distributed the nuclei of the parent syncytium. In both tissues nuclei are frequently found possessing varying amounts of cytoplasm which has not yet been transformed into the essential fibrils.

In addition to its enveloping membranes, which are wholly of white fibrous tissue, the white fibrous tissue supporting the central system within is quite abundant. It is all sent in from without, either as ingrowths of the pia mater, the most proximal of the membranes, or is carried in with the blood-vessels, of the walls of which it is an abundant component. Practically, the neuroglia as a connective tissue proper differs from white fibrous tissue only in origin and in its chemical or staining properties. Based upon the latter, there are methods of technique by which the two may be distinguished. White fibrous tissue is derived from the middle germ layer or the mesoderm, while neuroglia comes from the ectoderm. The epithelium lining the central canal of the spinal cord and the ventricles of the encephalon, with which the canal is continuous, is the remains of the mother tissue of the neuroglia, and in the adult is the only vestige indicating its origin. The cells of this epithelium are known as **ependymal cells,** and they are usually classed as a variety of neuroglia.

In its **development** the nervous system is precocious. It is the first of the systems to begin differentiation, and is the first to assume form. The first trace of the embryo appears on the developing ovum as the *embryonic area*, and the rapidly proliferating cells of that area shortly become arranged into the three germinal layers:—an outer layer or *ectoderm*, a middle layer or *mesoderm*, and an inner layer or *entoderm*. Early in the process of this arrangement there is formed along the axial line of the embryonic area a thickened plate of ectodermal cells, the *neural plate*. In the proliferation of these cells the margins of the neural plate, which lie parallel with the long axis of the embryonic area, rise slightly above the general surface, forming the *neural folds*, and the floor of the plate between the folds undergoes a slight invagination, the process resulting in the *neural groove* (fig. 559). As development proceeds and the embryonic area assumes the form of the distinct embryo, the neural folds or lips of the groove gradually converge, and, beginning anteriorly, finally unite. Thus the groove is converted into the *neural tube*, extending along the dorsal mid-line and enclosed within the body of the embryo by the now continuous ectoderm above. For a time the neural tube remains connected with the inner surface of the general ectoderm along the line of fusion by a strand of ectodermal cells, the *neural crest*. This crest is derived from the ridges of cells which composed the transition between the lips of the original groove and the general ectoderm, and whose fusion aided in the closure of the tube. The essential elements of the entire nervous system together with the neuroglia tissue are derived from the cells of the neural tube and the cells of the neural crest.

Even before the caudal extremity of the tube is entirely closed, the cephalic portion undergoes marked enlargement and becomes differentiated into three vesicular dilations, the *primary vesicles*. By a series of further dilations, flexures of its axis, and localised thickenings of its walls, the portion of the tube included in the three primary vesicles developes into the encephalon or brain. The remainder of the tube becomes the spinal cord.

The walls of the posterior vesicle give rise to the *rhombencephalon*, the cerebellum developing from its dorsal wall and the pons and medulla oblongata from its ventral wall. Its cavity persists and enlarges into the fourth ventricle of the adult.

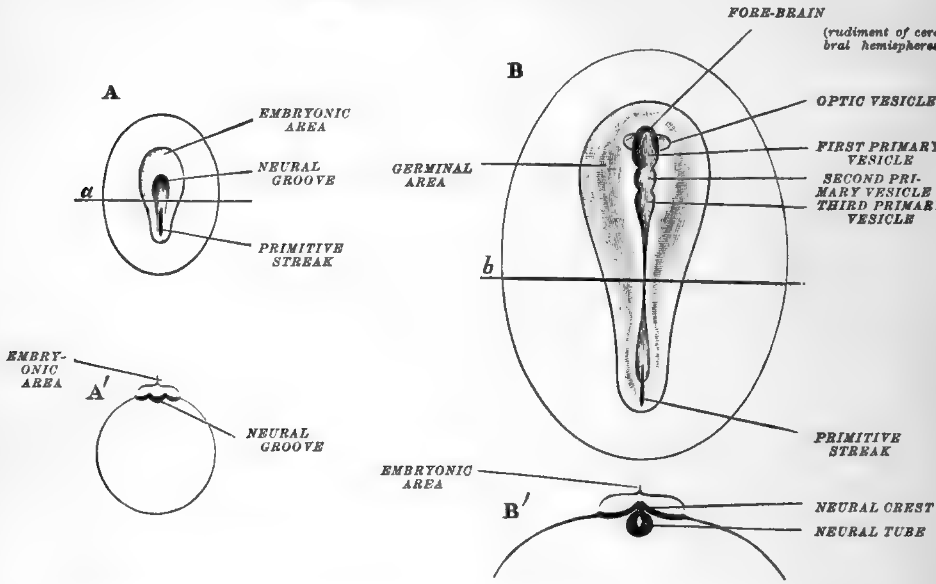
From the middle primary vesicle comes the *mesencephalon*, the corpora quadrigemina being formed from its dorsal and the cerebral peduncles from its ventral wall.

The anterior or first primary cerebral vesicle undergoes greater changes than either of the others. At an early period three diverticula are given off from its anterior extremity, two lateral and one mesial. The lateral are the primary optic vesicles and the mesial is the rudiment of the **cerebral hemispheres** or telencephalon. The remaining portion of the vesicle becomes the **diencephalon,** or inter-brain, its lateral walls thickening into the **thalami,** the posterior portion of its dorsal wall giving off a diverticulum, the **epiphysis** or pineal body, and from its ventral wall projects a diverticulum which becomes the **hypophysis** with its tuber cinereum. The stalks of the two optic vesicles represent the course of the optic nerves, while from their extremities are developed the retinæ, portions of the ciliary bodies, and portions of the iris of each ocular bulb.

The mesial diverticulum soon after its formation divides into two secondary vesicles, each of which represents a **cerebral hemisphere** and each of which gives off ventrally from its anterior part a narrow, tube-like diverticulum which is transformed into the **olfactory bulb and olfactory tract** of the adult encephalon. As development proceeds the cavities of the olfactory diverticula become occluded in man. However, in many of those animals in which the olfactory apparatus attains greater relative development than in man the cavities persist as the olfactory ventricles. The optic vesicles never persist as ventricles in the adult.

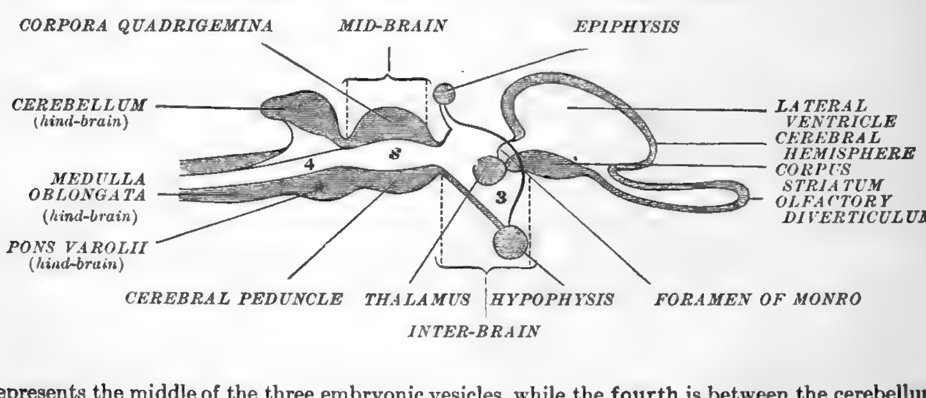
Fig. 559.—Diagrams of Surface Views and Sections of Germinal Areas showing the Development of the Neural Groove.

A. Earlier stage. B. Later stage. A′. Section through area A along the line *a*. B′. Section through area B along line *b*.



The adult human brain is characterised by the preponderant development of the cerebral hemispheres. These expand till, held within the cranial cavity, they extend posteriorly completely over the thalamencephalon and mesencephalon and overlap the cerebellum to its posterior border. Their cavities, which persist from the divided mesial diverticulum of the first or anterior embryonic vesicle, are correspondingly large, and comprise the two **lateral ventricles** (two of the four ventricles) of the adult brain. The **third ventricle** lies between the thalami and

Fig. 560.—Diagrammatic Sagittal Section of a Vertebrate Brain. (After Huxley.) 4, fourth ventricle; *s*, aqueduct of Sylvius; 3, third ventricle.

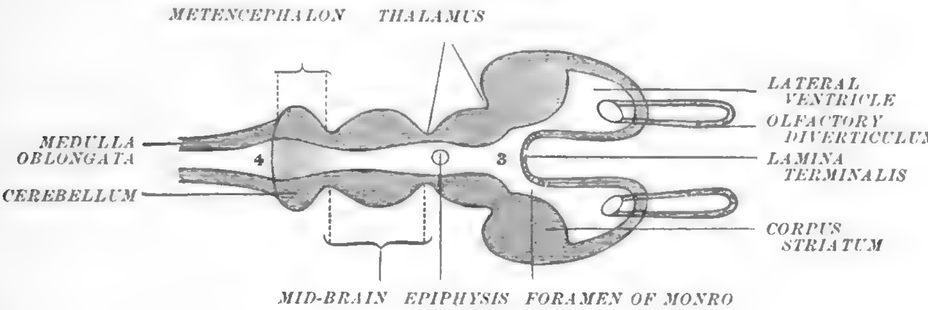


represents the middle of the three embryonic vesicles, while the **fourth** is between the cerebellum and medulla oblongata and represents the posterior of the primary vesicles. The four ventricles remain continuous with each other, as well as continuous with the central canal of the spinal cord. Both they and the central canal represent the persisting portion of the cavity of the original neural tube. The inter-ventricular foramina connecting the third ventricle with the two lateral ventricles are known as the **foramina of Monro**; that connecting the third ventricle

with the fourth or posterior ventricle passes under the corpora quadrigemina and is known as the **aqueduct of Sylvius,** or aquæductus cerebri.

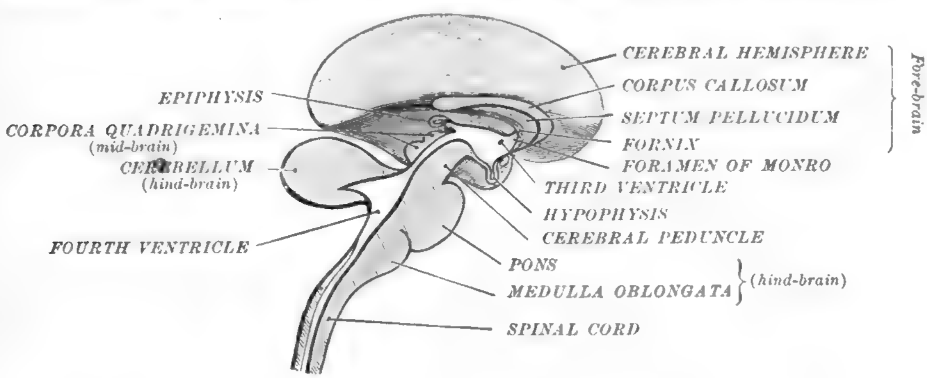
The localised thickening of the wall of the neural canal results from the combined proliferation and migration of its component cells. These proliferating cells have been called germinal

FIG. 561.—DIAGRAMMATIC HORIZONTAL SECTION OF A VERTEBRATE BRAIN. (After Huxley.)



cells. The products of their division are apparently indifferent at first, but later they become differentiated into two varieties:—(1) **Spongioblasts,** or those cells which will develope into neuroglia, and (2) **neuroblasts,** or those cells which will develope into neurones. The neuroblasts

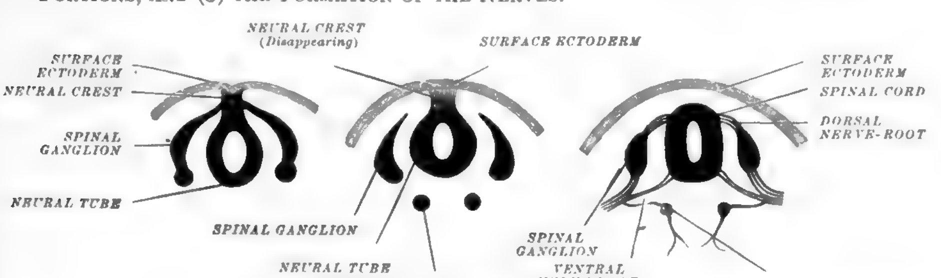
FIG. 562.—DIAGRAM SHOWING THE SEGMENTS AND THE FLEXURES OF THE HUMAN BRAIN AND THE EXPANSION OF THE CEREBRAL HEMISPHERES OVER THE OTHER PORTIONS OF THE BRAIN.



become transformed into neurones of the sizes, shapes, and arrangements characteristic of the localities in which the transformation occurs.

Neurones whose cell-bodies belong to the peripheral nervous system are not developed within the walls of the central system at all. They (comprising the spinal ganglion neurones and those

FIG. 563.—DIAGRAMS SHOWING (1) THE GROWTH OF THE PRIMITIVE GANGLIA FROM THE NEURAL CREST; (2) THE DIVISION OF THE PRIMITIVE GANGLIA INTO SPINAL AND SYMPATHETIC PORTIONS, AND (3) THE FORMATION OF THE NERVES.



of the sympathetic system) are derived from the cells of the neural crest. The wedge-shaped mass comprising the neural crest, through the proliferation of its cells, gradually extends outwards over the surface of the neural tube along either side. Soon the proliferation becomes

most rapid in regions corresponding to the mesodermic somites or primitive body segments, and the result is that the neural crest becomes segmented also. The segments or cell-masses thus formed are the beginning not only of the spinal ganglia, but also of the entire sympathetic system. The cell-masses of the crest migrate to assume a more lateral position, and then occurs a separation in their ranks. A portion of them remain in a dorso-lateral position near the wall of the neural tube and develope into the neurones of the **spinal ganglia** (the cerebro-spinal sensory neurones), but others wander further out into the periphery and become the neurones of the sympathetic. Certain of those of this more nomadic group settle within the vicinity of the vertebral column and form the **gangliated cord** or the proximal chain of sympathetic ganglia; others migrate further, but in more broken rank, and become the ganglia of the **prævertebral plexuses** or the intermediate chain, while still others wander into the very walls of the peripheral organs and occur singly or in groups in such plexuses as those of Auerbach and Meissner, between the tunics of the walls of the alimentary canal. Scattered along between these proximal, intermediate, and distal groups there are to be found small straggling ganglia, many of which contain so few cell-bodies that they are indistinguishable with the unaided eye. These sympathetic neurones, however, are always either directly or indirectly in connection with and largely under the control of the neurones of the central system through efferent fibres passing either viâ the rami communicantes or in the peripheral distribution of the cerebro-spinal nerves.

From the foregoing it will be seen that a **ganglion** may be defined as an aggregation of cell-bodies of neurones whether sympathetic or cerebro-spinal. As growth proceeds these cell-bodies send out their processes for the reception and transmission of nerve impulses. The cellifugal process, the axone, being in the majority of cases the longer process, is more in evidence. Every ganglion, therefore, will have connected with it bundles of nerve-fibres, some of which bear impulses to its cells from neighbouring ganglia or from the tissues of neighbouring organs: others of which arise from its cells and bear impulses to other ganglia or to the tissues of the organs. Necessarily, the larger the ganglion, the larger will be these bundles of fibres. In the peripheral system the larger of these bundles are given the general name of **nerves,** the smaller are spoken of as **branches, rami,** etc. In the central system the larger pathways, especially if mixed, are **funiculi,** the smaller and those composed of axones of similar functional course are called **fasciculi.**

THE CENTRAL NERVOUS SYSTEM

The central nervous system or organ is an aggregation of ganglia—a large ganglionated axis situated in the dorsal mid-line of the body—and the bundles of fibres connecting it with the tissues of other systems and with the peripheral ganglia are of necessity correspondingly large. So numerous are the axones connecting these ganglia and so intimately are they associated that a disturbance affecting any one part of the system may extend to influence all other parts. The enlarged cephalic extremity of this central axis, the **encephalon,** is a special aggregation of ganglia, many of which are much larger than any others found in the body.

In the study of the central nervous system its enveloping membranes or meninges are met with first, and logically should be considered first, but since a comprehensive description of these membranes involves a foreknowledge of the various structures with which they are related, it is more expedient to consider them after making a closer study of the entire system they envelope.

For convenience of study the central nervous system is separated into the general gross divisions illustrated in fig. 564. Each of these divisions will be subdivided and considered with especial reference to its anatomical and functional relations to the other divisions and the inter-relations of its component parts.

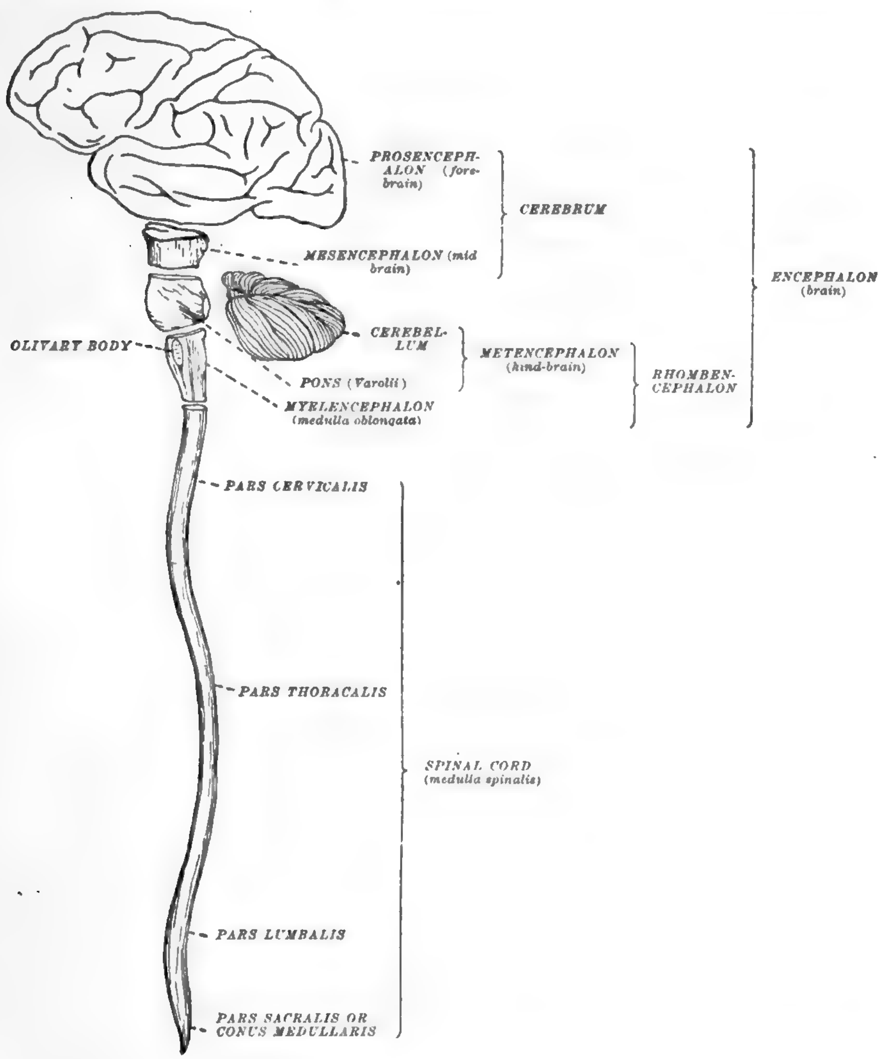
THE SPINAL CORD

The spinal cord or *medulla spinalis* is the posterior and most attenuated portion of the central nervous system. It is approximately cylindrical in form and terminates conically. Its average length in the adult is 44 cm. (18 in.). It averages about 2 cm. longer in the male than in the female. It weighs from 26 to 28 gm. or about 2 per cent. of the entire cerebro-spinal axis, and has about $\frac{1}{50}$ the weight of

the encephalon. After birth it grows more rapidly and for a longer period than the encephalon, increasing in weight more than sevenfold, while the brain increases less than half that amount. Its specific gravity is given as 1·038.

The line of division between the spinal cord and the medulla oblongata is arbitrary. The outer border of the foramen magnum is commonly given, or, better, a transverse line just below the decussation of the pyramids. Lying in the vertebral canal, the adult cord usually extends to the upper border of the body of the second lumbar vertebra. However, cases may be found in which it extends no farther than the last thoracic vertebra. Up to the third month of intra-uterine life it occupies

Fig. 564.—Diagram illustrating the Gross Divisions of the Central Nervous System.



the entire length of the vertebral canal, but owing to the fact that the vertebral column lengthens more rapidly and for a longer period than does the spinal cord, the latter, being attached to the brain above, soon ceases to occupy the entire canal. At birth its average extent is to the body of the third lumbar vertebra.

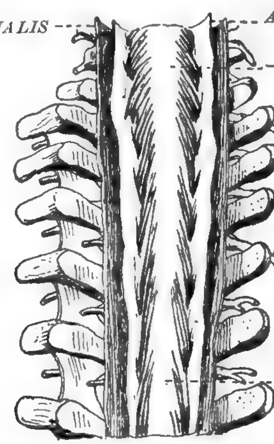
External morphology.—In position in the body, the spinal cord conforms to the curvatures of the canal in which it lies. In addition to the bony wall of the vertebral canal, it is enveloped and protected by its three membranes or meninges, which are continuous with the like membranes of the encephalon: first, the **pia mater,** which closely invests the cord and sends ingrowths into its substance,

contributing to its support; second, the **arachnoid,** a loosely constructed, thin membrane, separated from the pia mater by a considerable **subarachnoid space;** third, the **dura mater,** the outermost and thickest of the membranes, separated from the arachnoid by merely a slit-like space, the **subdural space.**

The intimate association of the central system with all the peripheral organs is attained chiefly through the spinal cord, and this is accomplished by means of thirty-one pairs of spinal nerves, which are attached along its lateral aspects. The nerves of each pair are attached opposite each other at more or less equal intervals along its entire length, and in passing to the periphery they penetrate the meninges, which contribute to and are continuous with the connective-tissue sheaths investing them. Each nerve is attached by two roots, an afferent or **dorsal root,** which enters the cord along its postero-lateral sulcus, and an efferent or **ventral root,** which makes its exit along the ventro-lateral aspect.

With its inequalities in thickness and its conical termination the spinal cord is subdivided into four parts or regions:—(1) The **cervical portion,** with eight pairs of cervical nerves; (2) the **thoracic portion,** with twelve pairs of thoracic nerves; (3) the **lumbar portion,** with five pairs of lumbar nerves; and (4) the **conus medullaris,** or sacral portion, with five pairs of sacral and one pair of coccygeal nerves. From the termination of the conus medullaris, the pia mater continues below in the subarachnoid space into the portion of the vertebral canal not occupied by the

Fig. 565.—Dorsal View of Portion of Spinal Cord in Position in Vertebral Canal.



spinal cord, and forms the non-nervous, slender, thread-like terminal, the *filum terminale.* This becomes continuous with the dura mater at its lower extremity.

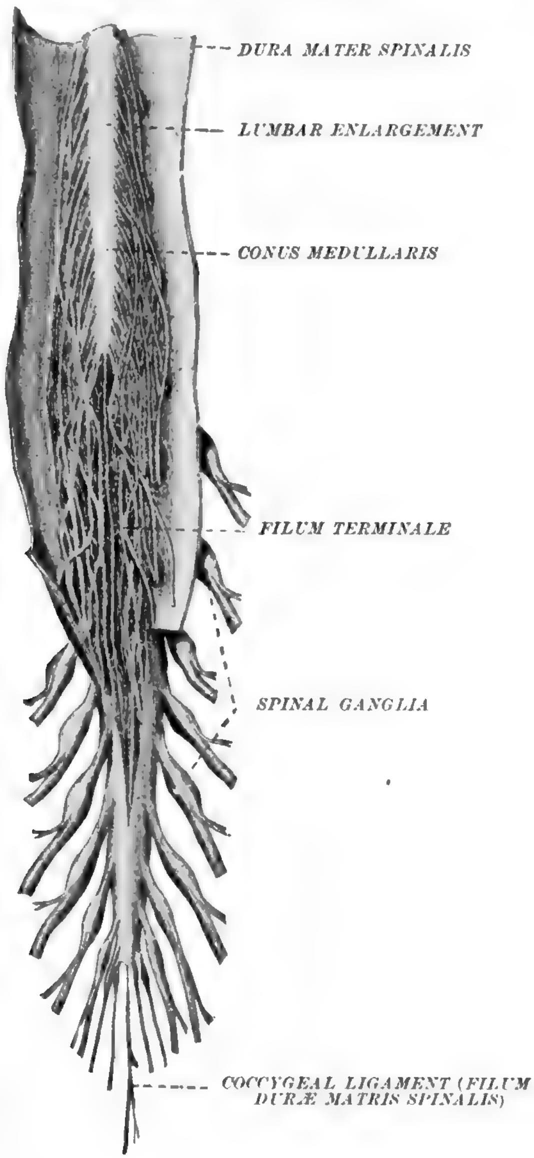
In the early fœtus the spinal nerves pass from their attachment to the spinal cord outwards through the intervertebral foramina at right angles to the long axis of the cord, but, owing to the fact that the vertebral column increases considerably in length after the spinal cord has practically ceased growing, the nerve-roots become drawn caudad from their points of attachment, and, as is necessarily the case, their respective foramina are displaced progressively downwards as the termination of the cord is approached, until finally the roots of the lumbar and sacral nerves extend downwards as a brush of parallel bundles considerably below the levels at which they are attached. This brush of nerve-roots is the *cauda equina.* The dura mater, being more closely related to the bony wall of the canal than to the spinal cord, extends with the vertebral column and thus envelopes the cauda equina, undergoing a slightly bulbous, conical termination.

The enlargements.—Wherever there is a greater mass of tissue to be innervated, the region of the nervous system supplying such must of necessity possess a greater number of neurones. Therefore, the regions of the spinal cord associated with the skin and musculature of the regions of the superior and inferior limbs are thicker than the regions from which the neck or trunk alone are innervated. Thus in the lower cervical region the spinal cord becomes broadened into the **cervical enlargement,** and likewise in the lumbar region occurs the **lumbar**

enlargement. The spinal nerves attached to these regions are of greater size than in other regions.

The cervical enlargement begins with the third cervical vertebra, acquires its greatest breadth (12 to 14 mm.) opposite the lower part of the fifth cervical vertebra (origin of the sixth cervical nerves), and extends to opposite the second thoracic vertebra. Unlike the lumbar enlargement, its lateral is noticeably greater than its dorso-ventral diameter.

Fig. 566.—Drawing from Specimen showing Cauda Equina, the Beginning of Certain of the Spinal Nerves which form it, and its Accompanying Dura Mater. (Dorsal aspect.)



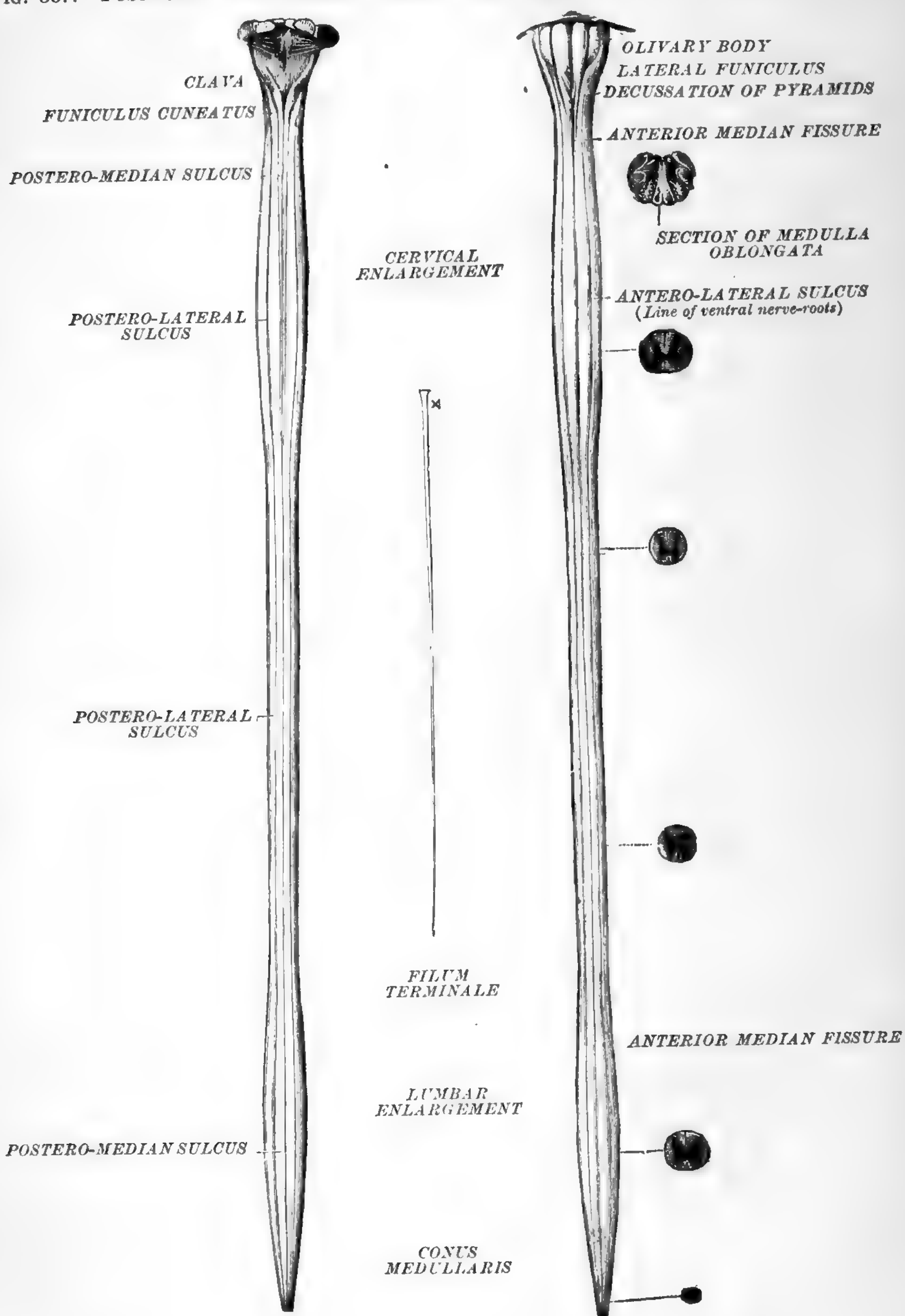
The lumbar enlargement begins gradually with the ninth or tenth thoracic vertebra, is most marked at the twelfth thoracic vertebra (origin of the fourth lumbar nerves), and rapidly diminishes into the conus medullaris.

Both the lumbar and thoracic regions are practically circular in transverse section. Neither diameter of the lumbar is ever so great as the lateral diameter of the cervical enlargement. The thoracic part attains its smallest diameter opposite

the fifth and sixth thoracic vertebræ (attachment of the seventh and eighth thoracic nerves).

The enlargements occur with the development of the upper and lower limbs. In

Fig. 567.—Posterior and Anterior Views of the Spinal Cord. (Modified from Quain.)

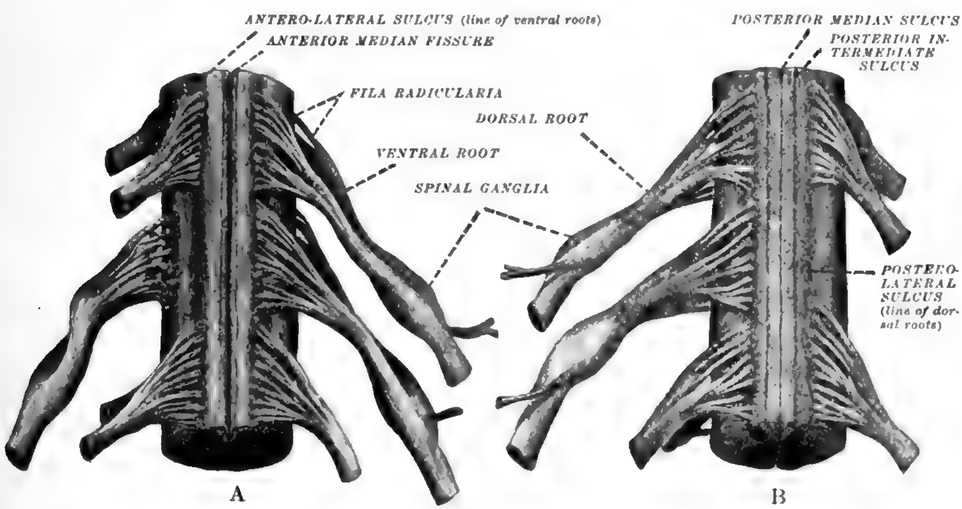


the embryo they are not evident until the limbs are formed. In the orang-utan and gorilla the cervical enlargement is greatly developed; the ostrich and emu have practically none at all.

Surface of the spinal cord.—The cord is separated into nearly symmetrical

right and left halves by the broad **anterior median fissure** into which the pia mater is duplicated, and opposite this, on the dorsal surface, by the **posterior median sulcus.** Along the lower two-thirds of the cord this sulcus is merely a septum; in the medulla oblongata it opens up and attains the character of a fissure, and finally becomes continuous into the fourth ventricle. Each of the two lateral halves of the cord is marked off into a posterior, lateral, and anterior division by two other longitudinal sulci. Of these, the **postero-lateral sulcus** occurs as a slight groove 2 to 3½ mm. lateral from the posterior median sulcus, and is the groove in which the dorsal roots enter the cord in regular linear series. The ventral division is separated from the lateral by the **antero-lateral sulcus.** This is rather an irregular, linear area than a sulcus. It is from 1 to 2 mm. broad, and represents the area along which the efferent fibres make their exit from the cord to be assembled into the respective ventral roots. This area varies in width according to the size of the nerve-roots, and, like the postero-lateral sulcus, its distance from the mid-line varies according to locality, being greatest on the enlargements of the cord. In the cervical region, and in part of the thoracic, the posterior division is subdivided by a delicate longitudinal groove, the **postero-intermediate sulcus,** which becomes more evident towards the medulla oblongata and represents the line of demarcation between the fasciculus gracilis and the fasciculus cuneatus. Occasionally in the upper cervical

Fig. 568.—A, Ventral, and B, Dorsal, Views of Portion of Spinal Cord showing Modes of Attachment of Dorsal and Ventral Roots.



region a similar line may be seen along the ventral aspect close to the anterior median fissure. This is the **antero-intermediate sulcus,** forming the lateral boundary of the ventral pyramidal fasciculus.

Collectively, the entire space between the posterior median sulcus and the line of attachment of the dorsal roots is occupied by the **posterior funiculus;** the lateral space between the line of attachment of the dorsal and that of the ventral roots, by the **lateral funiculus;** and the space between the ventral roots and the anterior median fissure, by the **anterior funiculus.** Each of these funiculi is subdivided into its component fasciculi.

The dorsal and ventral nerve-roots are not attached to the cord as such, but are first frayed out into numerous thread-like bundles of axones which are distributed along their lines of entrance and exit. These bundles are the **root filaments (fila radicularia)** of the respective roots. The fila of the larger spinal nerves are fanned out to the extent of forming almost continuous lines of attachment, while in the thoracic nerves there are appreciable intervals between those of adjacent roots. Throughout, the intervals are less between the fila of the ventral than between those the dorsal roots.

Internal structure of the spinal cord.—By reflected light masses of medullated axones appear white, and such masses are known as **white substance.** Masses

in which cell-bodies of neurones, non-medullated axones, and supporting tissue predominate have a darker or greyish appearance, and are known as **grey substance.** The spinal cord consists of a continuous, centrally placed column of grey substance surrounded by a variously thickened tunic of white substance. The closely investing pia mater sends numerous ingrowths into the cord, bearing blood-vessels and contributing to its internal supporting tissue. The volume of white and of grey substance varies both absolutely and relatively at different levels of the cord. The absolute amount of grey substance increases with the enlargements. The absolute amount of white substance also increases with the enlargements coincident with the greater amount of grey substance in those regions. The relative amount of white substance increases in passing from the conus medullaris to the medulla oblongata, due to the fact that the ascending and descending axones connecting the cord with the encephalon are contributed at different levels of the cord along its entire course.

The grey substance.—In the embryo all the nerve-cells of the grey substance are derived from the cells lining the neural tube, and in the adult the column of grey substance, though greatly modified in shape, still retains its position about the central canal. In transverse section the column appears as a grey figure of two laterally developed halves, connected across the mid-line by a more attenuated portion, the whole roughly resembling the letter H. The cross-bar of the H is known as the **grey commissure.** Naturally, it contains the **central canal,** which is quite small and is either rounded or laterally or ventrally oval in section, according to the level of the cord in which it is examined. The canal continues upwards, and in the medulla oblongata opens out into the fourth ventricle. Downwards, in the extremity of the conus medullaris, it widens slightly and forms the rhomboidal sinus or **terminal ventricle,** then is suddenly constricted into an extremely small canal extending a short distance into the filum terminale, and there ends blindly. The grey commissure always lies somewhat nearer the ventral than the dorsal surface of the cord, and itself contains a few medullated axones which vary in amount in the different regions of the cord. Of these, the axones crossing the mid-line on the ventral side of the central canal form the ventral or **anterior white commissure;** those, usually much fewer in number, crossing on the dorsal side of the central canal, form the dorsal or **posterior white commissure.** The axones of these commissures serve in functionally associating the two lateral halves of the grey column.

Each lateral half of the grey column presents a somewhat crescentic or comma-shaped appearance in transverse section, which also varies at the different levels of the cord. At all levels each half presents two vertical, well-defined horns, themselves spoken of as columns of grey substance. The **dorsal horn,** or *columna posterior*, extends posteriorly and somewhat laterally towards the surface of the cord along the line of the postero-lateral sulcus. It is composed of an **apex** (**caput**) and a **neck (cervix).** In structure the apex is peculiar. The greater portion of it consists of a mass of small nerve-cells and neuroglia tissue, among which a gelatinous substance of questionable origin predominates, giving the horn a semi-translucent appearance. This is designated as **gelatinous substance of Rolando,** to distinguish it from a similar appearance immediately about the central canal (*central gelatinous substance*). The apex of the dorsal horn is widest in the regions of the enlargements and the gelatinous substance of Rolando is most marked in the cervical region. In these regions the cervix consists of a slight constriction of the dorsal horn between the apex and the line of the grey commissure. In the thoracic region, however, the base of the cervix is the thickest part of the dorsal horn. This thickness is due to the presence there of the **nucleus dorsalis,** or Clarke's column—a column of grey substance containing numerous nerve-cells of larger size than elsewhere in the dorsal horn, and extending between the seventh cervical and third lumbar segments of the cord. Tapering finely at its ends, this nucleus attains its height in the lower thoracic or first lumbar segment. About the ventral periphery of the nucleus dorsalis are scattered nerve-cells of the same type as contained in it. These cells compose **Stilling's nucleus.** They are more numerous about the lower extremity of the nucleus dorsalis, and they continue to appear below its termination in the lumbar region.

The **ventral horn,** or *columna anterior*, of each lateral half of the grey figure is directed ventrally towards the surface of the spinal cord, pointing towards the antero-lateral sulcus. It contains the cell-bodies which give origin to the efferent or ventral root axones, and these axones make their emergence from the spinal cord along

the sulcus. The ventral horns vary markedly in shape in the different regions. In certain segments each ventral horn clearly presents its two component columns of grey substance: the **lateral horn** (*columna lateralis*), a triangular projection of grey substance into the surrounding white substance, in line with or a little ventral to the line of the grey commissure; and the **ventral horn proper** (*columna anterior*), projecting ventrally. In the mid-thoracic region the lateral horn is relatively insignificant, and the anterior horn is quite slender; in the cervical and lumbar enlargements both horns are considerably enlarged and fuse into one large column.

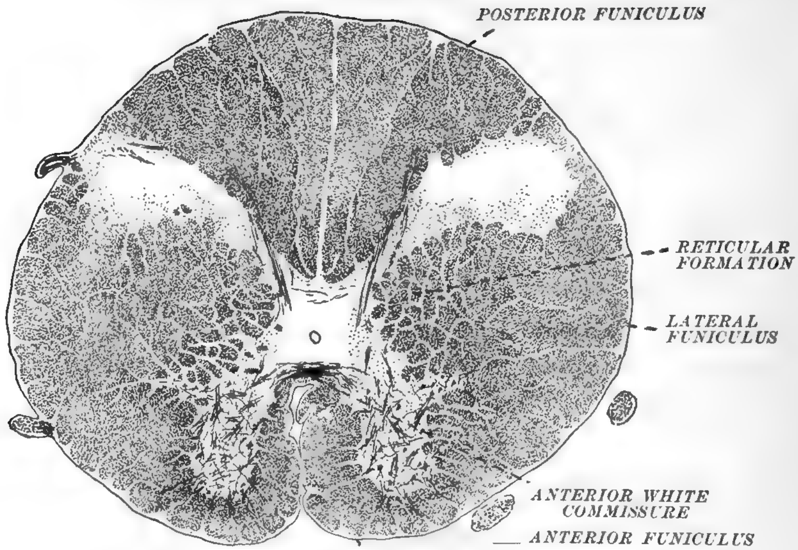
The grey substance is not sharply demarcated from the white. In the blending of the two there often are small fasciculi of white substance embedded in the grey, and likewise the grey substance sends fine processes among the axones composing the white substance. Such processes or grey trabeculæ are most marked along the lateral aspects of the grey figure and present there the appearance known as the **reticular formation.** The reticular formation of the spinal cord is most evident in the cervical region (fig. 569).

The large cell-bodies of the ventral horn as a whole are divisible into four groups, only two of which are to be distinguished in the mid-thoracic region of the spinal cord:—(1) A *ventral group* of cells, sometimes separated into a ventro-lateral and a ventro-medial portion (see figs. 569 and 571), occupies the anterior column, is constant throughout the entire length of the cord, and contributes axones to the ventral root, most of which probably supply the muscles proximal to the spinal column; (2) a *dorso-medial group* of cells, situated in the medial part of the ventral horn, just below the level of the central canal, gives origin to axones some of which go to the ventral root of the same side, but most of which cross the mid-line viâ the anterior white commissure, either to pass out in the ventral root of the opposite side or to enter the white substance of that side and course upwards or downwards, associating with other levels of the cord. Some of its axones terminate among the cells of the ventral horn in the same level of the opposite side; (3) a *lateral group* of cells, sometimes separated into a dorso-lateral and a ventro-lateral portion, occupies the lateral column of the horn, and is best differentiated in the cervical and lumbar enlargements. Most of the axones arising from its larger cells are contributed to the ventral root of the same side, and such axones probably supply the muscles of the extremities. Some of those from its ventral portion are distributed to the muscles of the body-wall; (4) an *intermediate group*, occupying the mid-dorsal portion of the ventral horn. Axones arising from its cells are probably seldom contributed to the ventral root, but instead course wholly within the central nervous system. Some pass to the opposite side of the cord, chiefly viâ the anterior and possibly the posterior white commissure, to terminate either in the same or different levels of the grey column. Others of longer course pass to the periphery of the cord, join one of the cerebello-spinal fasciculi, and pass upwards to the cerebellum.

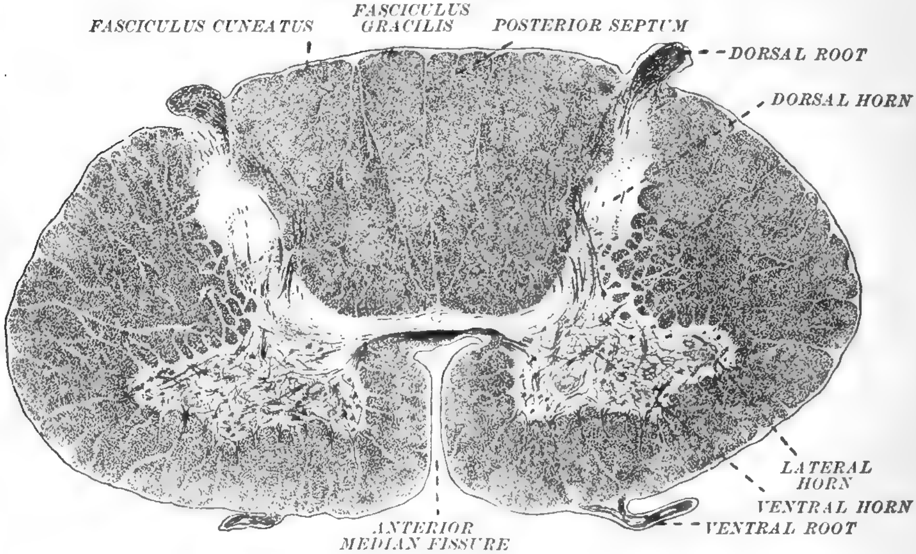
Furthermore, there are scattered throughout the grey substance many smaller nerve-cells. These give rise to axones of shorter course, either **commissural** or **associational** proper. Of such axones many are quite short, coursing practically in the same level as that in which their cells of origin are located, and serve to connect the different parts of the grey substance of that level. Others course varying distances upwards and downwards for the association of different levels of the grey column.

It is evident from the above that in addition to the various nerve-cells it contains, there is also to be found a felt-work of axones in the grey substance. Many of these axones are medullated, though not in sufficient abundance to destroy the grey character of the substance. The felt-work is composed of three general varieties of fibres:—(1) The terminal twigs of axones and their collaterals entering from the fasciculi of the white substance and forming end-brushes about the various cell-bodies in the grey substance (partly medullated); (2) axones given off from the cells of the grey substance and which pass into the surrounding white substance either to enter the ventral roots or to join the ascending and descending fasciculi within the spinal cord (partly medullated); (3) axones of Golgi cells of type II, which do not pass outside the confines of the grey substance (non-medullated). Some axones of any of these varieties may cross the mid-line and thus become commissural. In general all fibres of long course acquire medullary sheaths a short distance from their cells of origin, and lose them again just before termination.

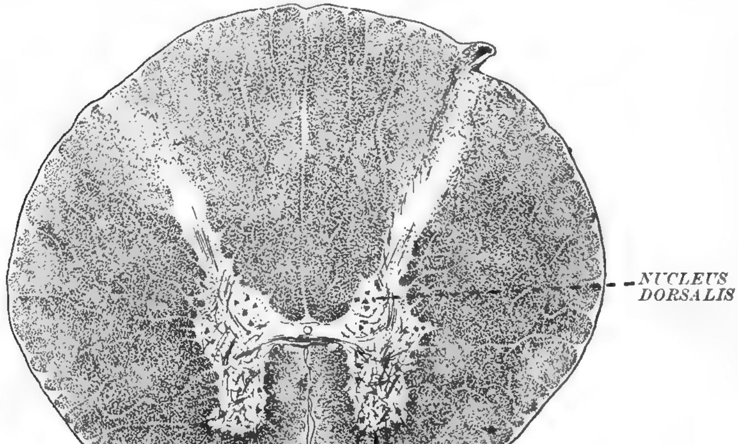
The white substance of the spinal cord.—The great mass of the medullated



Cervical II



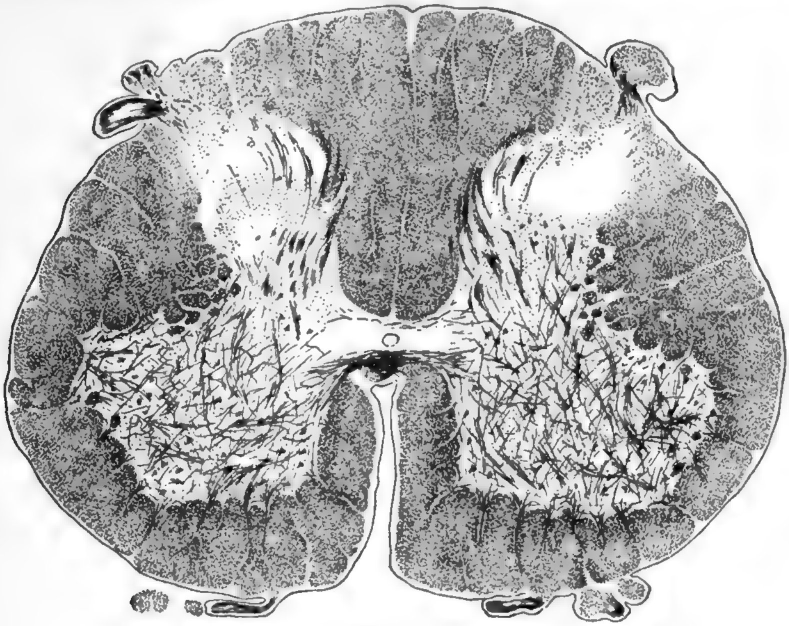
Cervical VI



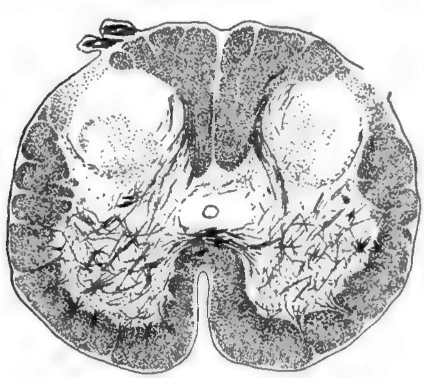
Thoracic VIII

Fig. 569.—(*Continued.*)

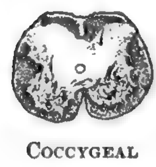
Fig. 569.—Transverse Sections from Different Segments of the Spinal Cord, showing Shape and Relative Proportions of Grey and White Substance in the Different Segments Represented.



Lumbar III



Sacral IV



Coccygeal

axones of the spinal cord course longitudinally and thus coursing, form the thick mantle surrounding the column of grey substance. This mantle is divided into right and left homolateral halves by the anterior median fissure along its ventral aspect, and along its dorsal aspect by the posterior septum, which is for the most part a connective-tissue partition derived from the pia mater along the line of the posterior median sulcus. The mantle is supported internally by interwoven neuroglia and white fibrous connective tissue, the latter, derived chiefly from the pia mater, closely investing it without.

The axones of the white substance belong to three general neurone systems:—(1) The *cerebro-spinal system*, which consists of axones of long course both ascending and descending, forming conduction paths between the cerebrum and the peripheral organs. The ascending axones of this system collect the general bodily sensations and convey them to the cerebrum, the cells of which in response contribute axones which descend the cord, conveying efferent or motor impulses. (2) The *cerebello-spinal* system consists of conduction paths, both ascending and descending, which are connections between cerebellar structures and the grey substance of the spinal cord. (3) Axones which serve to *associate* the different levels of the spinal cord. The axones of this system are proper to the spinal cord, i. e., they do not pass outside its confines. Necessarily this system contains axones of various lengths. Some merely associate different levels within a single segment of the cord; others associate the different segments with each other. Axones which associate the structures of the spinal cord with those of the medulla oblongata may be included in this system.

Both the first and second systems increase in bulk as the cord is ascended. The ascending axones of each system are contributed to the white substance of the cord along its length, and therefore accumulate upwards; the axones descending from the encephalon are distributed to the different levels of the cord along its length, and therefore diminish downwards.

The mass of the third system of axones varies according to locality. Wherever there is a greater mass of neurones to be associated, as there is in the enlargements of the cord, a greater number of these axones is required. Their cells of origin, being in the grey substance of the cord, contribute to its bulk and thus both the cells and the axones of this association system serve to make the enlargements more marked. In the lumbar and sacral regions the greater mass of the entire white substance consists of axones belonging to this system. It forms a dense felt-work about the grey column throughout its length. Many of these axones cross the mid-line to associate the neurones of the two sides of the grey column. For purposes of distinction, such as cross the mid-line are called **commissural fibres,** while those which course upwards and downwards on the same side are **association fibres.** Coursing in longitudinal bundles about the grey figure, they compose the **fasciculi proprii** or 'ground bundles' of the spinal cord.

A purely anatomical examination of a normal adult cord, prepared by whatever means, gives no indication of the fact that the mass of longitudinally coursing fibres of the white substance is composed of more or less definite bundles or fasciculi, each having a definite course, and whose axones form links (conduction paths) in a definite system of neurone chains.

Present information as to the size, position, and connections of the various fasciculi is based upon evidence obtained by three different lines of investigation:—

(1) **Physiological investigation.**—(*a*) Direct stimulation of definite bundles or areas in section and carefully noting the resulting reactions which indicate the function and course of the axones stimulated. (*b*) 'Wallerian degeneration' and the application of such methods as that of Marchi. When an axone is severed, that portion of it which is separated from its parent cell-body degenerates. Likewise a bundle of axones severed, whether by accident or design, will degenerate from the point of the lesion on to the locality of their termination in whichever direction this may be. By the application of a staining technique which is differential for degenerated or degenerating axones and a study of serial sections containing the axones in question, their course and distribution may be determined. The locality of their cells of origin, if unknown, may be determined by repeated experiment till a point of lesion is found not followed by degeneration of the axones under investigation. (*c*) The axonic reaction or 'reaction from a distance.' Cell-bodies whose axones have been severed undergo chemical change and stain differently from those whose axones are intact. Thus cell-bodies giving origin to a bundle of severed axones may be located in correctly stained sections of the region containing them.

(2) **Embryological evidence.**—In the first stages of their development axones of the cerebro-spinal nervous system are non-medullated. They acquire their sheaths of myelin later. Axone pathways forming different connections become medullated at different periods. Based upon this fact a method of investigation originated by Flechsig is employed, by which the position and course of various pathways may be determined. A staining method differential for medullated axones alone is applied to the nervous systems of fœtuses of different ages, and pathways medullated at given stages may be followed from the locality of their origin to their termination. In the later stages, when most of the pathways are medullated and therefore stain alike, the less precocious pathways may be followed by their absence of medullation.

(3) **Direct anatomical evidence.**—Stains differential for axones alone are applied to a given locality to determine the fact that the axones of a given bundle actually arise from the cell-bodies there, or that axones traced to a given locality actually terminate about the cell-bodies of that locality. For example, it may be proved anatomically that the axones of a dorsal root arise from the cells of the corresponding spinal ganglion, and then these axones may be traced

into the spinal cord and their terminations noted either by collateral or terminal twigs, or the fasciculus they join in their cephalic course may be determined.

For topographical purposes, that the various fasciculi may be referred to with greater ease, the white substance of the spinal cord in section is divided into three areas known as funiculi or columns and which correspond to the funiculi already mentioned as evident upon the surface of the cord when intact. The funiculi are outlined wholly upon the basis of their position in the cord and with reference to the median line and the contour of the column of grey substance; their component fasciculi are defined upon the basis of function. (1) The *posterior funiculus* or column is bounded by the posterior septum and the line of the dorsal horn; (2) the *lateral funiculus* or column is bounded by the lateral concavity of the grey column and the lines of entrance and exit of the dorsal and ventral roots; (3) the *ventral funiculus* or column is bounded by the mesial border of the ventral horn and by the anterior median fissure.

The posterior funiculus or column.—This column is composed of two general varieties of axones arranged in five fasciculi. First, and constituting the predominant type in all the higher segments of the cord, are the afferent or general sensory axones, which arise in the spinal ganglia, enter the cord by the dorsal roots, assume their distribution to the neurones of the cord, and then take their ascending course towards the encephalon. The axone of the spinal ganglion neurone undergoes a T-shaped division a short distance from the cell-body, one limb of this division terminating in the peripheral organs and the other going to form the dorsal root. Upon entering the cord the dorsal root axones undergo a Y-shaped bifurcation in the neighbourhood of the dorsal horn, one branch ascending and the other descending. Their ascending branches form the **fasciculus gracilis** (Goll's column) and the **fasciculus cuneatus** (Burdach's column). These fasciculi are the chief ascending or sensory cerebrospinal connections, the direct sensory path to the cerebrum. The neurones represented in them constitute the first link in the neurone chain between the periphery of the body and the cerebral cortex. In threading their way towards the brain, these sensory axones tend to work towards the mid-line. Therefore those of longer course are to be found nearer the posterior septum, in the upper segments of the cord, than those axones which enter the cord by the dorsal roots of the upper segments. Thus it is that the fasciculus gracilis, the medial of the two fasciculi, contains the axones which arise in the spinal ganglia of the sacral and lumbar segments. In other words, it is the fasciculus bearing sensory impulses from the lower limbs to the brain, while the fasciculus cuneatus, the lateral of the two, is the corresponding pathway for the higher levels. Naturally, there is no fasciculus cuneatus as such in the lower segments of the spinal cord. The axones being much blended at first, it is only in the cervical region that there is any anatomical demarcation between the two fasciculi. In this region the two become so distinct that there is in some cases an apparent connective-tissue septum between them, continuing inwards from the postero-intermediate sulcus—the surface indication of the line of their junction.

Upon reaching the medulla oblongata the fibres of the fasciculus gracilis and the fasciculus cuneatus terminate about cells grouped to form the nuclei of these fasciculi. The nucleus of the fasciculus gracilis is situated medially and begins just below the point at which the central canal opens into the fourth ventricle; the nucleus of the fasciculus cuneatus is placed laterally and extends somewhat higher than the other nucleus. The neurones whose cell-bodies compose these nuclei constitute the second links in the neurone chains conveying sensory impulses from the periphery to the cerebral cortex.

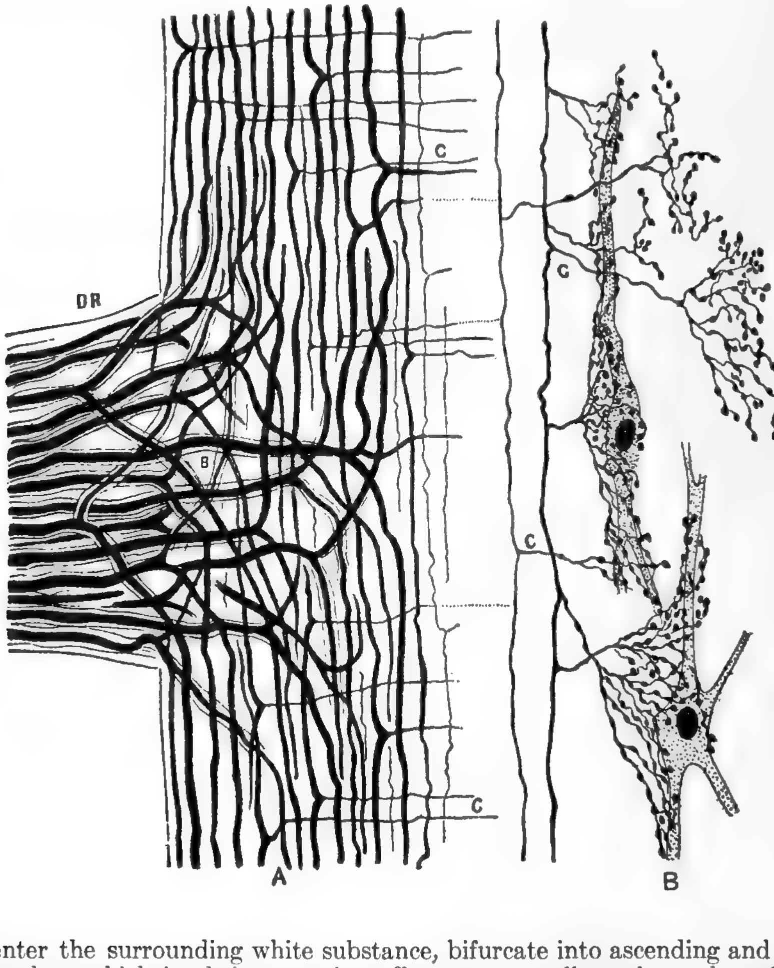
The descending or *caudad branches* of the dorsal root axones are concerned wholly with the neurones of the spinal cord. They descend varying distances, some of them as much as four segments of the cord, and give off numerous collaterals on their way to the cells of the grey column. Those terminating about cell-bodies of the ventral horn which give rise to the ventral or motor root-fibres, are responsible for certain of the so-called *'reflex activities'* and thus contribute to the simplest of the **reflex arcs.** In descending they serve to associate different levels of the grey substance of the cord with impulses entering by way of a single dorsal root. Some of their collaterals cross the mid-line in the posterior white commissure, and thus become connected with neurones of the opposite side. The caudad branches of longer course are scattered throughout the ventral portion of the fasciculus cuneatus (*middle root zone*), but show a tendency to collect along the border-line between the fasciculus cuneatus and the fasciculus gracilis, and thus contribute largely to the **comma-shaped fasciculus.** Also many of them course in the **oval bundle** or septo-marginal root zone.

The ascending branches of the dorsal root axones also give off collaterals to the grey substance of the cord, thus extending the area of distribution of a given posterior nerve-root to levels of the cord above the region at which the root enters.

The greater number of the terminations of dorsal root axones within the spinal cord are concerned with neurones other than those contributing ventral root-fibres. The greater mass of the neurones concerned are those contributing the **fasciculi proprii** or **ground bundles** of the spinal cord, or the second variety of axones composing the posterior funiculus. The latter fasciculi arise from the smaller cells of the grey column.

FIG. 570.—SHOWING DISPOSITION OF THE DORSAL ROOT-FIBRES UPON ENTERING SPINAL CORD. (From Edinger. after Cajal.)

A, shows dorsal root axones DR, entering the spinal cord, bifurcating B. and giving off collaterals C to the neurones of the cord. B shows the terminal twigs of these axones or of their collaterals displayed upon cell-bodies of the grey substance of the cord.



They enter the surrounding white substance, bifurcate into ascending and descending branches, which in their turn give off numerous collaterals to the cells of the grey substance of the levels through which they pass. The cell-bodies giving origin to such axones are so numerous that the entire column of grey substance is surrounded by a continuous felt-work of axones of this variety.

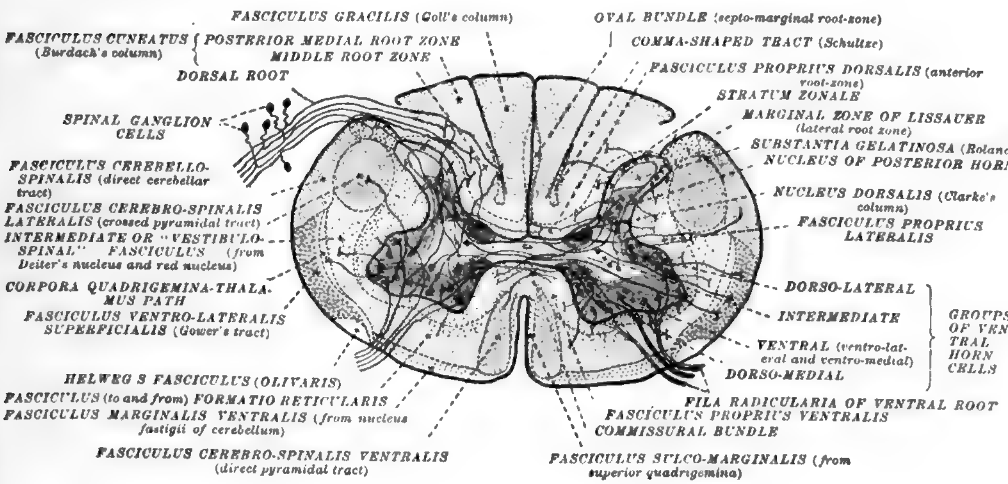
The **dorsal fasciculus proprius** (anterior root zone of posterior column) arises chiefly from cells situated in the dorsal horn (*stratum zonale*). Coincident with the ingrowth and arrangement of the fasciculi gracilis and cuneatus many fibres of the dorsal fasciculus proprius go to form both the oval bundle and the comma-shaped fasciculus. Thus these two bundles are mixed, being fasciculi proprii which contain caudad branches of dorsal root axones. The '*median triangle*' is formed by the continuation of the dorsal fasciculi proprii with the oval or septo-marginal fasciculus.

Some of the axones of the dorsal fasciculus proprius cross the mid-line to distribute impulses to the neurones of the opposite side. These commissural axones, together with certain collaterals of the dorsal root axones, which cross the mid-line outside the dorsal white commissure, compose the so-called **cornu-commissural tract** at the base of the posterior septum.

The lateral funiculus or column.—Not all the axones of the posterior or dorsal nerve-roots extend to the encephalon. Estimation shows that the sum of all the dorsal roots is greatly in excess of the sum contained in the fasciculi cuneatus and gracilis just before these enter their nuclei of termination. Therefore many of the ascending dorsal root axones are concerned with spinal-cord connections wholly. The **marginal zone of Lissauer,** situated along the lateral margin of the postero-lateral sulcus, is composed largely of dorsal root axones. Many of these finally work across the line of the sulcus into the posterior column. Many of the dorsal root-fibres which do not reach the brain occur in Lissauer's zone. Many others, of course, occur throughout the posterior column. Lissauer's zone also contains some fibres arising from the small cells of the dorsal horn, and to this extent corresponds to a fasciculus proprius.

The **lateral fasciculus proprius** (lateral ground bundle, lateral limiting layer)

FIG. 571.—SCHEMATIC REPRESENTATION OF THE SHAPE AND POSITION OF THE VARIOUS FASCICULI OR CONDUCTION PATHS OF THE SPINAL CORD AND THE GROUPING AND SIGNIFICANCE OF THE CELL-BODIES OF THE GREY SUBSTANCE. (Compiled from the schemes of von Lenhossèk and Held.)



is situated in the lateral concavity of the grey column and is continuous with the other fasciculi proprii both dorsal and ventral. Beyond that it probably does not contain commissural axones, it is of the same general significance as the others. It is frequently divided into small bundles by the reticular formation.

The lateral cerebro-spinal fasciculus (crossed pyramidal tract). In contrast to the sensory fibres passing through the spinal cord to the cerebral cortex, axones are given off from the pyramidal cells of the cortex, which descend to terminate about the cells of the grey substance of the spinal cord, chiefly the cells which give origin to the ventral root-fibres. Upon reaching the medulla oblongata in their descent, these axones are accumulated into two well-defined, ventrally placed bundles, the **pyramids,** one from each cerebral hemisphere. In passing through the brain stem the pyramids contribute many fibres to the motor nuclei of the cranial nerves, and thus decrease appreciably in bulk. According to the estimate of Thompson, about 160,000 of the pyramidal fibres are destined to enter the spinal cord.

Upon reaching the lower part of the medulla, the greater mass of the fibres of each pyramid, which are destined to enter the cord, suddenly cross the mid-line in the 'decussation of the pyramids.' The remainder retain their ventral position in

their descent of the cord. The crossed pyramidal fibres course in the lateral column ventral to Lissauer's zone, and lateral to the lateral fasciculus proprius, and form the *lateral cerebro-spinal fasciculus* (crossed pyramidal tract). It is a large fasciculus, oval shaped in transection, and since its axones terminate in the grey column of the cord all along its length, it decreases in bulk as the cord is descended.

In addition to the three dispositions of the dorsal root axones given above, certain of them, either by collaterals or terminal twigs, form end-brushes about the cells of the nucleus dorsalis (Clarke's column). The axones given off by these cells pass to the dorso-lateral periphery of the lateral funiculus, and there collect to form the **cerebello-spinal fasciculus** (direct cerebellar tract of Flechsig). As such they ascend without interruption, and in the upper level of the medulla oblongata pass into the cerebellum by way of the inferior cerebellar peduncle or restiform body. Necessarily, this fasciculus is not evident in levels below the extent of the nucleus dorsalis.

Also situated superficially in the lateral funiculus is another ascending conduction path, and, like the cerebello-spinal fasciculus, to which it is adjacent, it is also in part at least a cerebellar connection. Its position suggests its name, **superficial ventro-lateral fasciculus** (Gowers' tract). This tract at present does not include as great an area in transverse section as when originally described. The more internal portion of the original Gowers' tract is now given a separate significance, and will be considered separately. While the exact location in the grey column of all the cell-bodies giving origin to the superficial antero-lateral fasciculus is uncertain, it is known that certain ventral horn cells contribute their axones to it. Many of its cells of origin are scattered in the area immediately ventral to the nucleus dorsalis, others in the intermediate and mesial portion of the lateral group of ventral horn cells. In the lumbar region these cells are quite numerous, and, therefore, the fasciculus begins at a lower level in the spinal cord than does the direct cerebellar tract. In degenerations it becomes visible in the upper segments of the lumbar region, and has been proved to increase notably in volume as the cord is ascended. Its axones arise for the most part directly from cell-bodies of the same side of the cord, though it has been shown by several investigators that some of its axones come from the grey substance of the opposite side by way of the ventral white commissure. Terminal twigs and collaterals of the posterior root-fibres, mostly of the same side, but occasionally from the opposite side, terminate about its cells of origin. At one time Gowers' tract was considered an entity, but now, even in the more limited area it occupies, it must be considered a mixture of axones of several terminal destinations or distinct neurone systems. The destination of some of its axones has not been determined with certainty. A portion go to the cerebellum, and there have been traced to the cortex of the superior vermis. Most of these reach the cerebellum not by way of the restiform body, as does the lateral cerebello-spinal tract, but pass on in the brain-stem to the level of the inferior corpora quadrigemina, and there turn back to join the brachium conjunctivum or superior cerebellar peduncle. (Auerbach, Mott, Hoche.) Only a few of its axones leave the fasciculus lower down in the medulla, to enter the cerebellum by way of the restiform body, in company with the lateral cerebello-spinal tract. (Rossolimo, Tschermak.) Another portion of its axones are thought to reach the cerebrum, probably the nucleus lentiformis, though it has not been positively traced further than the superior corpora quadrigemina. Many axones in Gowers' tract of the cord correspond to those of the fasciculi proprii, and merely run varying distances in the cord, to turn again into its grey substance. Schaeffer followed some of these from the lumbar region up to the level of the second cervical nerve.

In the ventral border of Gowers' tract and immediately upon the periphery, near the anterior lateral sulcus (exit of ventral nerve-roots), there is found in the higher segments of the cord a small oval bundle, the **olivary fasciculus** or **Helweg's** (Bechterew's) **bundle.** The functional direction of its fibres has not been settled. It is asserted to be a connection of the olive in the medulla oblongata, and in the cord is believed to be connected with the cells of the ventral column of grey substance, probably those of the lateral horn. By some observers it has been traced as far down as the mid-thoracic region; by others, however, only as far as the third cervical segment. The olives being nuclei largely concerned with cerebellar connections, Helweg's fasciculus is probably an indirect cerebellar connection with the

spinal-cord neurones. It is composed of fibres of relatively very small diameter, and it is one of the last fasciculi of the cord to become medullated.

Situated between the superficial ventro-lateral cerebello-spinal fasciculus and the lateral fasciculus proprius is an area which, in transverse section, by position, may be referred to as the **intermediate fasciculus** (mixed lateral zone). It contains a mixture of at least four varieties of axones:—(1) It is said to contain descending fibres from the cerebellum, to connect with the neurones of the spinal cord, probably the ventral root or motor neurones; (2) fibres from the red nucleus of the tegmentum (in the mesencephalon), which probably form indirect cerebellar connections with the spinal-cord neurones; (3) fibres from Deiters' nucleus or the nucleus lateralis of the vestibular nerve, in the upper portion of the medulla oblongata, thus connecting the spinal-cord neurones with the auditory apparatus; (4) the most lateral portion of the intermediate fasciculus, the region at one time included in Gowers' tract, contains fibres from the corpora quadrigemina and the thalamus, thus probably connecting the spinal cord with the optic apparatus as well as with the auditory. These fibres are thought to terminate chiefly in contact with the neurones of the fasciculi proprii, but to some extent directly with those giving origin to the ventral or motor nerve-roots. A portion of the intermediate fasciculus has been designated as *Loewenthal's tract.*

The anterior funiculus or column.—The *intermediate fasciculus* is continued ventrally and mesially across the line of exit of the ventral root axones, and thus into the anterior funiculus. This portion is also mixed, but its axones of long course connect somewhat different portions of the nerve axis from those connected by the more lateral portion. According to the studies of Flechsig, von Bechterew, and Held, this mesial portion contains fibres, both ascending and descending, which connect the various levels of the grey substance of the spinal cord with the reticular formation of the medulla oblongata. The levels to which they have been traced contain the olivary nuclei, which are largely concerned in cerebellar connections, and the nuclei of the tenth, ninth, eighth, seventh, and the spinal tract of the fifth cranial nerves. Also they are probably associated with the nuclei of the eye-moving nerves. This portion of the intermediate fasciculus also grades into and is mixed with the axones of the **ventral fasciculus proprius,** as is its lateral portion with the lateral fasciculus proprius. In other words, the fasciculi proprii proper, the axones nearest the grey substance, serve for the intersegmental association of the different levels of the grey substance of the cord, while the intermediate fasciculus contains axones of longer course which serve to associate more distant levels of the grey substance of the nerve axis—that of the spinal cord with its upward continuation into the brain-stem.

The **anterior marginal fasciculus** (vestibulo-spinal tract, Loewenthal's tract) forms the superficial boundary of the mesial portion of the intermediate fasciculus. It is a narrow band, parallel with the surface of the cord, and extends mesially from the mesial extremity of Gowers' tract (from Helweg's bundle) to the beginning of the anterior median fissure. The axones belonging to it proper are descending from the recipient nuclei of the vestibular division of the auditory nerve. Of these nuclei it has been held by some investigators that only Deiters' nucleus (in the upper extremity of the medulla oblongata) gives origin to the axones of the anterior marginal fasciculus. Others agree with Tschermak that the superior and more laterally situated Bechterew's nucleus of the vestibular nerve also contributes axones to it. More recent investigations have shown that, in part at least, the anterior marginal fasciculus comes from the nucleus fastigii (roof nucleus) of the cerebellum. Since many axones from both Deiters' and Bechterew's nucleus terminate in the nucleus fastigii, the anterior marginal fasciculus is, in any case, a conduction path from the vestibular portion of the auditory apparatus to the grey substance of the spinal cord. The fasciculus is said to extend as far as the sacral region of the cord, its axones terminating about the cells of the ventral horns.

The **ventral cerebro-spinal fasciculus** (anterior or direct pyramidal tract), as stated above, is the uncrossed portion of the descending cerebro-spinal system of neurones. It is a small, oblong bundle, situated mesially in the anterior funiculus, parallel with the anterior median fissure. Like the lateral cerebro-spinal fasciculus (crossed pyramidal tract), its axones arise from the large pyramidal cells of the motor or somæsthetic area of the cerebral cortex, and transmit their impulses to the neurones of the ventral horns of the grey substance of the spinal cord, and almost

entirely to those neurones which give origin to the ventral or motor roots. It represents merely a delayed decussation of the pyramidal fibres, for instead of crossing to the opposite side in the lower portion of the medulla oblongata, as do the fibres of the lateral fasciculus, its fibres decussate all along its course, crossing in the ventral white commissure and in the commissural bundle of the cord to terminate about the ventral horn cells of the opposite side. Hoche, employing Marchi's method, found that a few of its fibres terminate in the ventral horn of the same side. This conforms to the pathological and experimental evidence that there are homolateral or uncrossed fibres in the crossed pyramidal tracts also. Like the crossed tract, the ventral pyramidal tract diminishes rapidly in volume as it descends the cord. Its loss is greatest in the cervical enlargement, and it is entirely exhausted in the thoracic cord. With the exception of the monkey, none of the mammalia below man, which have been investigated, possess this ventral pyramidal tract.

Lying between the ventral cerebro-spinal fasciculus and the pia mater of the anterior median fissure is a thin tract of descending axones continuous ventrally with the anterior marginal fasciculus. From its position it is known as the **sulco-marginal fasciculus.** The extent of its course in the spinal cord is uncertain. It arises from the cells of the grey substance of the superior pair of the corpora quadrigemina, and there, in largest part at least, it crosses the mid-line, and in the so-called 'optic acoustic reflex path' descends through the medulla oblongata into the spinal cord of the opposite side.

The **commissural bundle** is situated about the floor of the anterior median fissure, and is the most dorsal tract of the anterior funiculus. It contains decussating or commissural axones of three varieties:—(1) It contains the decussating axones of the ventral cerebro-spinal fasciculus throughout the extent of that fasciculus; (2) it is chiefly composed of the axones of the ventral fasciculus proprius which arise in the grey substance (ventral horn) of one side, cross the mid-line as commissural fibres, and course both upwards and downwards to be distributed to the neurones of different levels of the grey substance of the opposite side; (3) it contains decussating axones which arise from cell-bodies in the grey substance of one side and cross the mid-line to terminate about cell-bodies in practically the same level of the opposite side. The latter are merely axones belonging to the ventral white commissure which course without the confines of the grey figure. The commissural bundle is present throughout the length of the spinal cord, and is largest in the enlargements, i. e., where the association and commissural neurones occur in greater number generally. In its two last-mentioned varieties of axones it corresponds to the commissural portion of the dorsal fasciculus proprius.

The **ventral fasciculus proprius** is but a continuation of the lateral fasciculus proprius, and is composed of ascending and descending association fibres of the same general significance.

SUMMARY OF THE SPINAL CORD

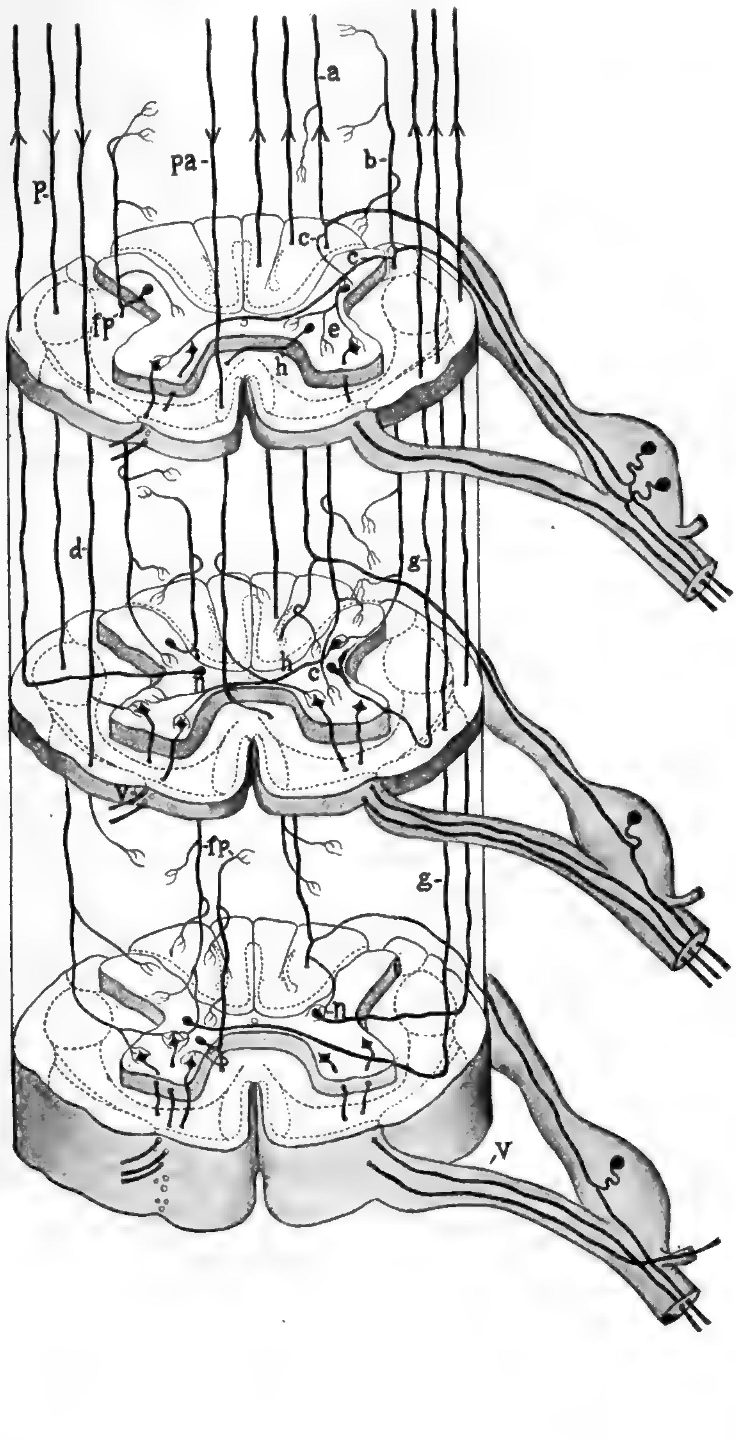
The spinal cord contains two general classes of axones arranged into three general systems. It contains axones which—(1) enter it from cell-bodies situated outside its boundaries, i. e., in the spinal ganglia and in the encephalon, and (2) axones which arise from cell-bodies situated within its own grey substance, some of which axones pass outside its boundaries both to the periphery and into the encephalon: some of which remain wholly within it. Its axones comprise—(1) a cerebro-spinal system, ascending and descending; (2) a cerebello-spinal system, ascending and descending, and (3) a system for the intersegmental association of its grey substance, both ascending and descending, association proper and commissural.

For these relations the grey substance of the cord contains three general classes of nerve-cells:—(1) those which give rise to the peripheral efferent or motor axones of the ventral roots; (2) those which give rise to central axones of long course, those going to the encephalon, and (3) those which supply its central axones of shorter course, the association and commissural systems.

In transverse sections of the spinal cord the relative area of white substance as compared with that of the grey increases as the cord is ascended. The absolute area

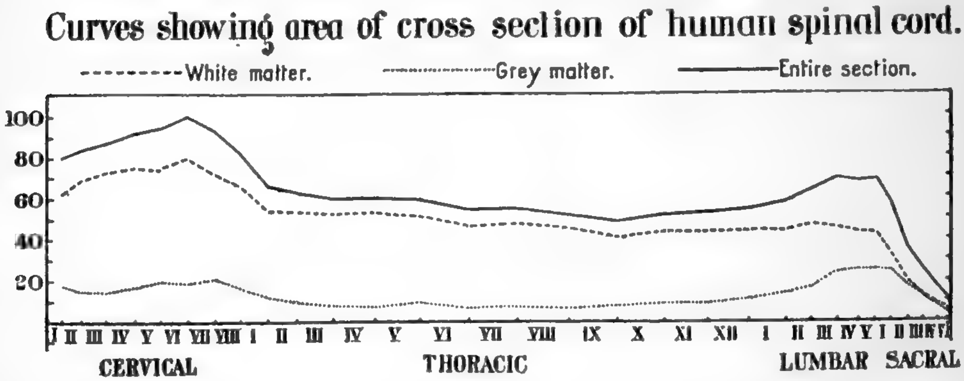
Fig. 572.—Schematic Representation of the More Important Architectural Relations of Neurones in the Spinal Cord.

a, afferent (spinal ganglion) axone to cerebrum with bifurcation and caudad branch; b, afferent axone coursing in Lissauer's zone and distributed wholly within the cord; c, collaterals of a and b disposed in three ways; p, pyramidal axone in lateral (crossed) cerebro-spinal fasciculus distributed to levels of grey substance; pa, axone in ventral cerebro-spinal fasciculus decussating before termination; v, ventral root or motor neurones; n, nucleus dorsalis giving axone to cerebello-spinal fasciculus; g, ascending neurones of Gowers' tract; d, descending axone from cerebellum; fp, neurones of fasciculi proprii association proper; h, commissural neurones; e, Golgi cell of type II.



of each varies with the locality, both being greatest in the enlargements. The grey substance predominates in the conus medullaris and lower lumbar segments. The white substance begins to predominate in the upper lumbar segments, not because of the increased presence of cerebro- and cerebello-spinal axones, but because of the increased volume of the fasciculi proprii coincident with the greater mass of grey substance to be intersegmentally associated in this region. In the thoracic region the

FIG. 573.—GRAPHIC REPRESENTATION OF THE VARYING AMOUNTS OF GREY AND WHITE SUBSTANCE AND OF THE VARIATIONS IN AREA OF ENTIRE SECTIONS OF THE DIFFERENT SEGMENTS OF THE SPINAL CORD. (From Donaldson and Davis.)
(Based upon measurements from several adult human spinal cords.)



predominating white substance is composed mostly of the axones of long course. The greatly increased amount of white substance in the cervical region is due both to the greater accumulation of cerebro- and cerebello-spinal axones in this region and to the increased volume of the fasciculi proprii of the cervical enlargement.

ORDER OF MEDULLATION OF THE FASCICULI OF THE CORD

The axones of the spinal cord begin to acquire their myelin sheaths during the fifth month of intra-uterine life. In general, axones which have the same origin and the same locality of termination—the same function—acquire their sheaths at the same time. While it has been proved that the medullary sheath does not necessarily precede the functioning of an axone, it may be said that those fasciculi which first attain complete and definite functional ability are the first to become medullated. At birth all the fasciculi of the spinal cord are medullated except Helweg's fasciculus, and occasionally the pyramidal tracts. As indicated by their medullation, those axones by which the cord is enabled to function as an organ *per se*, that is, the axones making possible the simpler reflex activities, complete their development before those axones which involve the brain with the activities of the cord.

According to Flechsig and van Gehuchten, and investigators succeeding them, the following is the order in which the axones of the cord become medullated:—

(1) The afferent and efferent nerve-roots and commissural fibres of the grey substance.

(2) The fasciculi proprii, first the ventral, then the lateral, and last the dorsal, fasciculus proprius.

(3) The fasciculus cuneatus (Burdach's column) and Lissauer's zone—the area of those ascending cerebro-spinal fibres which run the shorter course.

(4) Fasciculus gracilis (Goll's column).

(5) The cerebello-spinal fasciculus (direct cerebellar tract).

(6) The superficial antero-lateral fasciculus (Gowers' tract).

(7) The lateral cerebro-spinal fasciculus (crossed pyramidal) and the ventral cerebro-spinal fasciculus (direct pyramidal tract).

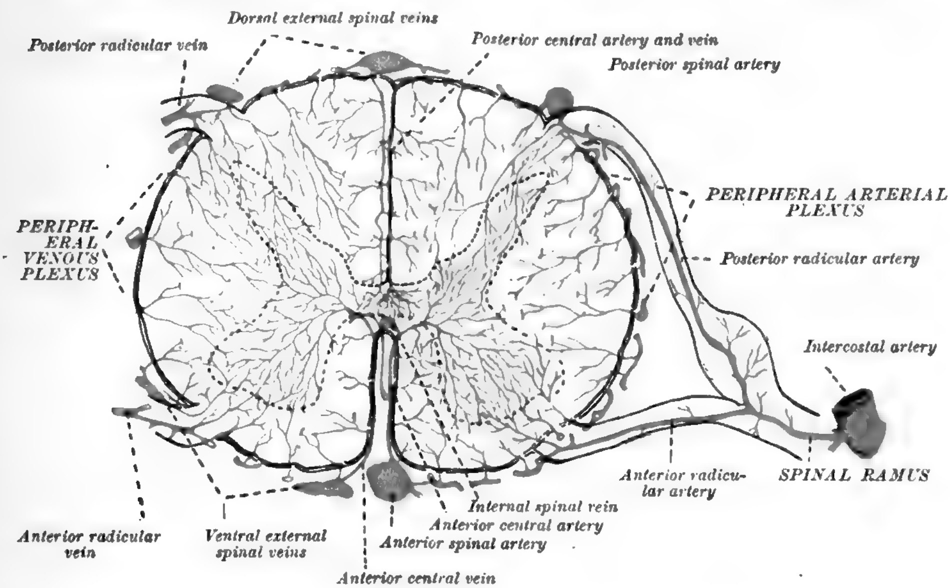
(8) Helweg's (Bechterew's) fasciculus.

The axones descending from the cerebellum and the brain-stem are so mixed with other axones that it is difficult to determine the sequence of their medullation. The fasciculi containing them also contain axones of the variety in the fasciculi proprii and so show medullation early. It is probable that the ascending cerebellar fibres acquire their myelin earlier than the descending.

Blood Supply of the Spinal Cord.

The spinal rami of the sacral, lumbar, intercostal, or vertebral arteries, as the case may be, accompany the spinal nerves through the intervertebral foramina, traverse the dura mater and arachnoid, and each divides into a dorsal and a ventral radicular artery. These accompany the nerve-roots to the surface of the cord, and there break up into an anastomosing plexus in the pia mater. From this plexus are derived three tortuously coursing longitudinal arteries and numerous independent central branches, which latter penetrate the cord direct. Of the longitudinal arteries, the **anterior spinal artery** zigzags along the anterior median fissure and gives off the anterior central branches, which pass into the fissure and penetrate the cord. These branches give off a few twigs to the white substance in passing, but their most partial distribution is to the ventral portion of the grey substance. The two **posterior spinal arteries,** one on each side, course along the lines of entrance of the dorsal root-fibres. They each branch and anastomose,

Fig. 574.—Semi-diagrammatic Representation of the Blood Supply of the Spinal Cord.



so that often two or more posterior arteries may appear in section upon either side of the dorsal root. These give off transverse or central twigs to the white substance, but especially to the grey substance of the dorsal horns. Of the remaining central branches many enter the cord along the efferent fibres of the ventral roots, and are distributed chiefly to the grey substance; others from the peripheral plexus throughout penetrate the cord and break up into capillaries within the white substance. Some of the terminal twigs of these also enter the grey substance. The blood supply of the grey substance is so much more abundant than that of the white substance that in injected preparations the outline of the grey figure may be easily distinguished by its abundance of capillaries alone. The central branches are of the terminal variety, that is, their capillaries do not anastomose with those of other branches. In the white substance the capillaries run for the most part longitudinally, or parallel with the axones.

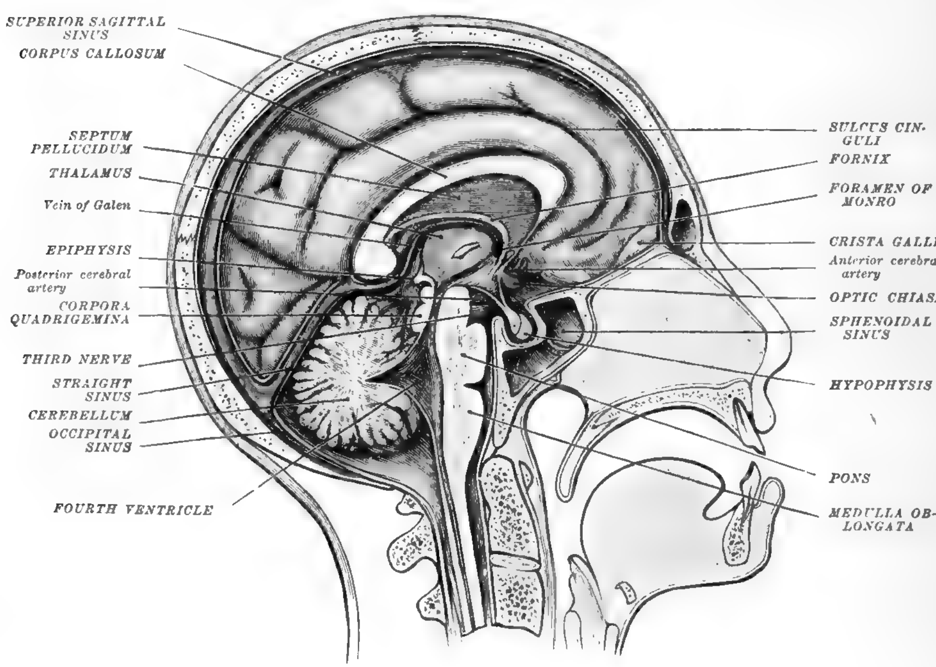
The *venous system* is quite similar to the arterial. The blood of the central arteries is collected into corresponding central venous branches which converge into a superficial venous plexus in which are six main longitudinal channels, one along the posterior median sulcus, one along the anterior median fissure, and one along each of the four lines of the nerve-roots. These comprise the **dorsal and ventral external spinal veins.**

The **internal spinal veins** course along the ventral surface of the grey commissure, and arise from the convergence of certain of the twigs of the *anterior central vein.* The *posterior central vein* courses along the posterior median septum in company with the posterior central artery, and empties into the *median dorsal vein.* The venous system communicates with the coarser extra-dural or internal vertebral plexus chiefly by way of the **radicular veins.**

THE BRAIN OR ENCEPHALON

The brain is that greatly modified and enlarged portion of the central nervous system which is enclosed within the cranial cavity. It is surrounded and supported by the same three membranes (meninges) that envelope the spinal cord. While there is a considerable subdural space, the brain more nearly fills its cavity than does the spinal cord. Exclusive of its dura mater, it weighs from 1100 to 1700 gm. (40–60 oz.), varying in weight with the stature of the individual or with the bulk of the tissues to be innervated. Its average weight is 1360 gm. (48 oz.) in males and 1250 gm. (44 oz.) in females. It averages about fifty times heavier than the spinal cord, or about 98 per cent. of the entire cerebro-spinal axis. In its precocious growth it is at birth relatively much larger than at maturity. At birth it comprises about 12 per cent. of the total body-weight, while at maturity it averages only about 2 per cent. of the weight of the body. Its proportion to the body-weight averages somewhat higher in smaller individuals. Its specific gravity averages 1.036.

Fig. 575.—Mesial Section of the Head of a Female Thirty-five Years Old.



The differences between the meninges of the brain and those of the spinal cord occur chiefly in the dura mater. (1) The *dura mater* is about double the thickness of that of the spinal cord, and consists of two closely adhering layers, the outermost of which serves as the internal periosteum of the cranial bones. (2) The inner layer is duplicated in places into strong partitions which extend between the great natural divisions of the encephalon. Of these, the sickle-shaped *falx cerebri* extends between the hemispheres of the cerebrum, the crescentic *tentorium cerebelli* extends between the cerebellum and the overlapping posterior portion of the cerebrum, and the smaller *falx cerebelli* occupies the notch between the hemispheres of the cerebellum. Contained within these partitions of the dura mater are the great collecting venous sinuses of the brain. These will be considered in the more detailed description of the cranial meninges.

General topography.—In its dorsal aspect or **convex surface** the encephalon is oval in contour, with its **frontal pole** usually narrower than its **occipital pole.** Viewed from above, the **cerebrum** comprises almost the entire dorsal aspect, the **occipital lobes** overlapping the **cerebellum** to such an extent that only the lateral and lower margins of the cerebellar hemispheres are visible. The **great longitudinal fissure** of the cerebrum, separating the cerebral hemispheres, begins on the ventral surface of the occipital lobes and extends anteriorly and ventrally between the frontal lobes, so as to be evident on the base of the brain.

Laterally the **temporal lobes,** with their rounded anterior extremities, the **temporal poles,** are each separated from the frontal and **parietal lobes** above by the **lateral cerebral fissure** (fissure of Sylvius). In the depths of this fissure and overlapped by the temporal lobe is situated the **insula, or island of Reil** (central lobe).

The surface of each cerebral hemisphere is thrown into numerous folds or curved elevations, the **gyri cerebri** or convolutions, which are separated from each other by slit-like fissures, the **sulci cerebri.** The gyri (and sulci) vary greatly in length and in their degrees of curvature. The larger and deeper of them are similar in the two hemispheres; most of them are individually variable, but each gyrus of one hemisphere is homologous with that of the like region of the other hemisphere. By gently pressing open the great longitudinal fissure, the **corpus callosum,** the chief commissural pathway between the cerebral hemispheres, may be seen. The occipital margin of this large transverse band of white substance is rounded and thickened into the **splenium** of the corpus callosum, while its frontal margin is curved ventrally into the **genu.**

The **base of the encephalon** is more irregular than the convex surface, and consists of a greater variety of structures. In the mid-line between the frontal lobes appears the anterior and inferior extension of the great longitudinal fissure. When the margins of this are separated, the outer aspect of the **rostrum** of the *corpus callosum,* the downward continuation of the curve of the genu, is exposed.

The inferior surface of each frontal lobe is concave, due to its compression upon the superior wall of the orbit. The *orbital gyri* with their respective *orbital sulci* occupy this concave area.

The cranial nerves (nervi cerebrales).—Along the mesial border of each orbital area, and parallel with the great longitudinal fissure, lie the **olfactory bulbs** continued into the **olfactory tracts.** Each olfactory bulb is the first central connection or 'nucleus of reception' of the **olfactory nerve,** the first of the twelve cranial nerves. A few fine filaments of this nerve may often be discerned penetrating the ventral surface of the bulb. They are non-medullated. The olfactory bulb and tract lies in the *olfactory sulcus,* which forms the lateral boundary of the *gyrus rectus,* the most mesial gyrus of the inferior surface of the frontal lobe. Upon reaching the area of Broca (area parolfactoria), or the region about the inner extremity of the gyrus rectus, each olfactory tract undergoes a slight expansion, the **olfactory tubercle,** and then divides into three roots or **olfactory striæ**—a medial, an intermediate, and a lateral, which comprise the **olfactory trigone.** The striæ begin their respective courses upon the **anterior perforated substance,** an area which contains numerous small foramina through which the antero-lateral group of central cerebral arteries enters the brain. This region forms the anterior boundary of that area of the basis encephali in which the substance of the brain becomes continuous across the mid-line.

At the inner boundary of the anterior perforated substance the **optic nerves** (the second pair of cranial nerves) come together and fuse to form the **optic chiasma.** Thence the **optic tracts** disappear under the poles of the temporal lobes in their backward course to the *thalami* and *corpora geniculata* or metathalami.

Immediately behind the optic chiasma occurs that diverticulum from the floor of the third ventricle known as the **tuber cinereum.** It is connected by its tubular stalk, the **infundibulum,** with the **hypophysis** or pituitary body, which occupies its special depression (sella turcica) in the floor of the cranium and is usually torn from the encephalon in the process of its removal. Behind the tuber cinereum are the two **mammillary bodies** (corpora albicantia), each of which is the superficial evidence of the fornix, one of the larger association fasciculi of the cerebrum. The **peduncles of the cerebrum** (crura cerebri) are the two great funiculi which connect the cerebral hemispheres with all the structures below them. They diverge from the anterior border of the **pons** (Varolii) and, one for each hemisphere, disappear under the poles of the temporal lobes. The pons (brachium pontis or middle cerebellar peduncle) is chiefly a bridge of white substance or commissure between the cerebellar hemispheres.

The **oculomotor** or third pair of cranial nerves make their exit from the **posterior perforated substance** in the **interpeduncular fossa** just behind the corpora mammillaria.

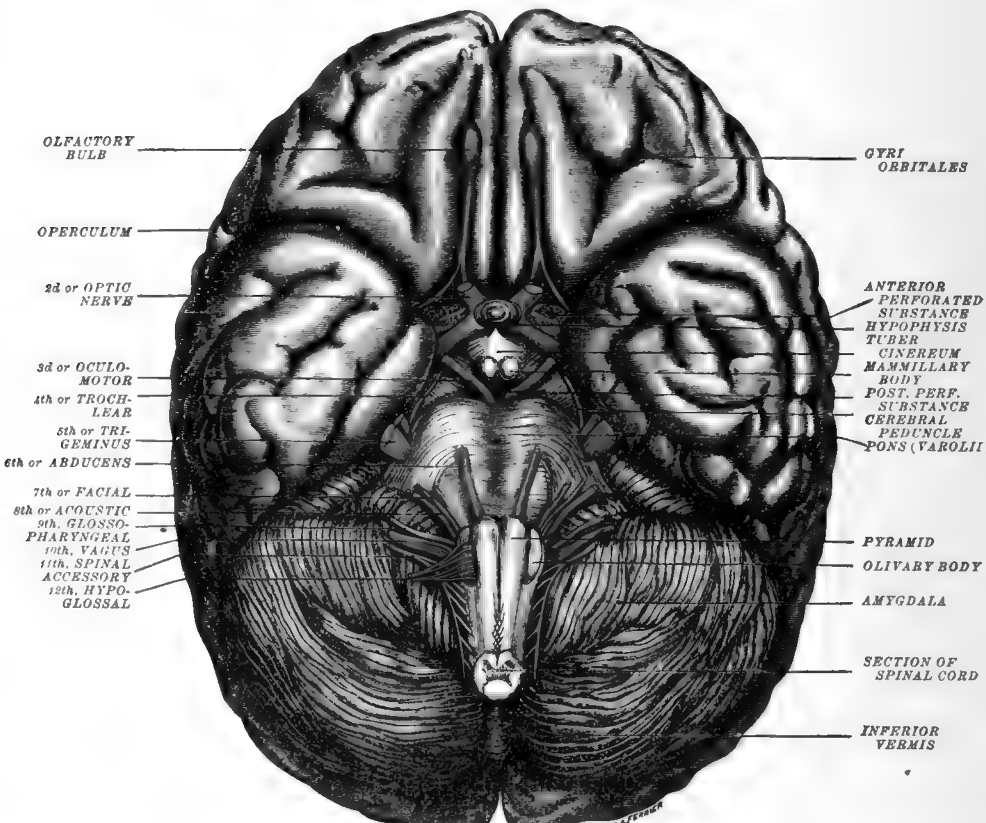
The **trochlear nerves,** or the fourth pair, emerge around the lateral aspects of the pedunculi cerebri along the anterior border of the pons. The fourth is the

smallest of the cranial nerves, and the only pair arising from the dorsal aspect of the brain. They undergo total decussation in the region of their exit, just behind the posterior quadrigeminate bodies.

The **trigeminus,** or fifth cranial nerve, is the largest. It penetrates the pons to find its recipient nuclei in the depths of the brain-stem. For the most part it is a sensory nerve, but it is accompanied by a small motor root (portio minor).

Three pairs of cranial nerves are attached to the brain-stem along the inferior border of the pons:—the **abducens** or sixth nerve emerges near the mid-line; the **facial** or seventh emerges from the more lateral aspect of the brain-stem; and the **acoustic** or eighth enters the extreme lateral aspect of the stem. The eighth consists of two parts, a *vestibular* and a *cochlear* division. The cochlear division courses for the most part externally and dorsally around the *inferior cerebellar peduncle,* giving it the appearance from which it derives its name, **'restiform body.'**

Fig. 576.—View of the Base of the Brain. (After Beaunis.)



The remaining four pairs of the cranial nerves are attached directly to the **medulla oblongata.** This comprises that portion of the brain-stem beginning at the posterior border of the pons above, and continuous with the first segment of the spinal cord below. On its ventral surface the **pyramids** and the **olives** are the two most prominent structures. The pyramids, which are continuous below into the pyramidal tracts of the spinal cord, form the two tapering prominences along either side of the anterior median fissure; the olives are the oblong oval elevations situated between the pyramids and the restiform bodies, and each is the superficial indication of the inferior olivary nucleus.

The **glosso-pharyngeal** or ninth nerve, the **vagus** (pneumogastric) or tenth, and the **spinal accessory** or eleventh cranial nerve are attached along the lateral aspect of the medulla oblongata in line with the facial nerve and between the olive and the corpus restiforme. The spinal accessory is assembled from a series of rootlets which

emerge from the lateral aspect of the first three or four cervical segments of the spinal cord, as well as from the medulla. It becomes fully formed before reaching the level of the olive, and passes outwards in company with the vagus. The root filaments of the vagus and glosso-pharyngeal are arranged in a continuous series, and, if severed near the surface of the medulla, those belonging to the one nerve are difficult to distinguish from those belonging to the other.

The **hypoglossal** or the twelfth and last of the cranial nerves emerges as a series of rootlets between the pyramid and the olive. Thus it arises nearer the mid-line, and in line with the abducens, trochlear, and oculomotor.

If the occipital lobes be lifted from the superior surface of the cerebellum and the tentorium cerebelli removed, the **corpora quadrigemina** (mesencephalon) may be observed. These are situated above the cerebral peduncles, in the region of the ventral appearance of the oculomotor and trochlear nerves. Resting upon the superior pair of the quadrigeminate bodies (colliculi superiores) is the **epiphysis** or pineal body, and just anterior to this is the cavity of the third ventricle, bounded laterally by the thalami and roofed over by the **tela chorioidea of the third ventricle** (velum interpositum).

By separating the inferior margin of the cerebellum from the dorsal surface of the medulla oblongata the lower portion of the **fourth ventricle** (rhomboid fossa) may be seen. The **cisterna cerebello-medullaris,** a subarachnoid space in this region, is occupied in part by a thickening of the arachnoid. This is continuous with the tela chorioidea (ligula) and plexus chorioidea of the fourth ventricle. The former roofs over the lower portion of the fourth ventricle, and, passing through it in the medial line, is the lymph passage, the **foramen** of **Magendie,** by which the cavity of the fourth ventricle communicates with the subarachnoid space. The fourth ventricle, as it becomes continuous with the central canal of the spinal cord, terminates in a point, the **calamus scriptorius.** From the inferior surface the cerebellar hemispheres are more definitely demarcated, and between them is the **vermis** or central lobe of the cerebellum.

Divisions of the encephalon.—The encephalon as a whole is developed from a series of expansions, flexures, and thickenings of the wall of the anterior portion of the primitive neural tube. Being continuous with the spinal cord, it is arbitrarily considered as beginning just below the level of the decussation of the pyramids, or at a line drawn transversely between the decussation of the pyramids and the level of the first pair of cervical nerves.

In its general conformation four natural divisions of the brain are apparent: the two most enlarged portions—(1) the cerebral hemispheres and (2) the cerebellum; (3) the corpora quadrigemina (mesencephalon) between the cerebral hemispheres and the cerebellum, and (4) the medulla oblongata, the portion continuous with the spinal cord. However, the most logical and advantageous arrangement of the divisions and subdivisions of the encephalon is on the basis of their development from the walls of the embryonic brain vesicles. On this basis, for example, both the medulla oblongata and the cerebellum with its pons are derived from the posterior of the primary vesicles, and are, therefore, included in a single gross division of the encephalon, viz., the *rhombencephalon.* In the following outline the anatomical components of the encephalon are arranged with reference to the three primary vesicles from the walls of which they are derived, and the primary flexures and thickenings of the walls of which they are elaborations.

During the early growth of the neural tube its basal or ventral portion acquires a greater thickness than the lateral portions and the roof of the tube, and thus the tube is longitudinally divided into a basal or **ventral zone** and an alar or **dorsal zone.** This is especially marked in the brain vesicles. Structures arising from the dorsal zone begin as localised thickenings of the roof. For example, in the rhombencephalon the greater part of the medulla oblongata and of the pons region is derived from the ventral zone, while the cerebellum is derived from the dorsal zone. The first of the flexures occurs in the region of the future mesencephalon, and is known as the **cephalic flexure;** next occurs the **cervical flexure,** at the junction with the spinal cord; third, the **pontine flexure,** in the region of the future fourth ventricle. Both the cervical and pontine flexures, while having a significance in the growth processes, are almost entirely obliterated in the later growth of the encephalon.

OUTLINE OF THE DIVISIONS OF THE ENCEPHALON

- Encephalon (Brain)
  - Rhombencephalon — Posterior primary vesicle.
    - Medulla oblongata—myelencephalon, I. (After-brain)
    - Metencephalon (Hind-brain)
      - Cerebellum, II_2,
      - Pons (Varolii), II_1.
      - *Middle part of fourth ventricle.*
    - Isthmus rhombencephali — III.
      - Superior cerebellar peduncles,
      - Anterior medullary velum,
      - *Superior part of fourth ventricle.*
  - Cerebrum
    - Mesencephalon (Mid-brain) — Middle primary vesicle.
      - Corpora quadrigemina, IV_2,
      - Cerebral peduncle (crura), IV_1,
      - Posterior perforated substance, IV,
      - *Aquæductus cerebri (Sylvii).*
    - Prosencephalon (Fore-brain) — Anterior primary vesicle.
      - Diencephalon (Inter-brain)
        - Thalamencephalon
          - Thalamus, V_2,
          - Metathalamus, V_3 (Corpora geniculata),
          - Epithalamus, V_4 (Epiphysis, pineal body).
        - Mammillary portion of hypothalamus, V_1,
        - *Posterior portion of third ventricle.*
      - Telencephalon (End-brain)
        - Optic portion of hypothalamus, VI_1 (Hypophysis),
        - Optic nerves and retinæ, VI,
        - *Anterior portion of third ventricle.*
        - Cerebral hemispheres
          - Corpus striatum, VI_2,
          - Olfactory bulb and tract, VI_3,
          - Cerebral cortex (pallium), VI_4,
          - *Lateral ventricles.*

FIG. 577.—MEDIAN SAGITTAL SECTION THROUGH EMBRYONIC HUMAN BRAIN AT END OF FIRST MONTH. (After His.)
(Showing the localities of origin of the derivatives of the three primary vesicles named in outline on p. 780.)

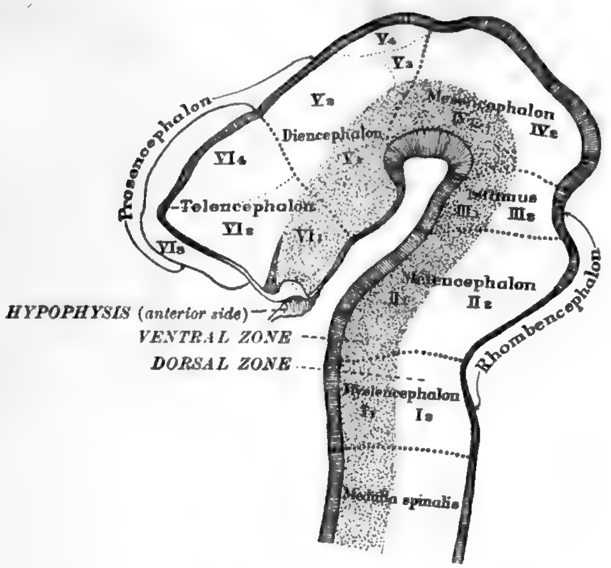
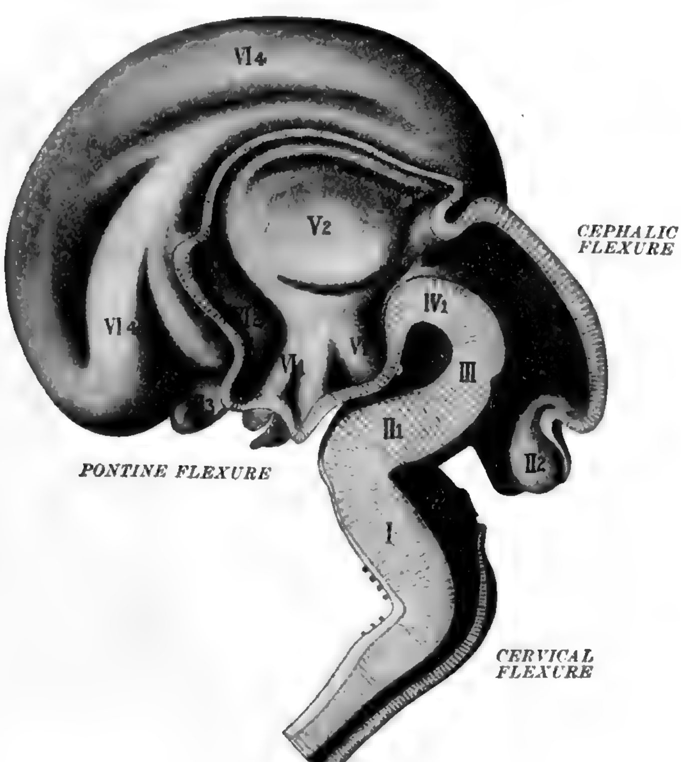
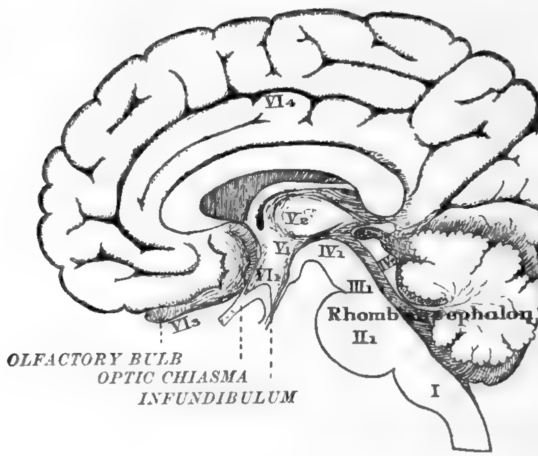


FIG. 578.—SAGITTAL SECTION OF BRAIN OF HUMAN EMBRYO OF THE THIRD MONTH. (After His.)
(Reference numerals correspond with those of fig. 577 and those after names of parts in outline on p. 780.)



The location of the development of the various parts of the encephalon may be determined, and their elaboration and changes in shape and position may be traced by comparing the accompanying figs. 577, 578, and 579. The reference numbers in

Fig. 579.—Median Sagittal Section of Adult Human Brain. (Drawing of model by His.) (Reference numerals same as in figs. 577 and 578.)



the figures correspond with the like numbers after the names of the parts on p. 780 in the outline of the divisions of the encephalon. The more detailed subdivisions of the parts will be met with in their individual descriptions.

THE RHOMBENCEPHALON

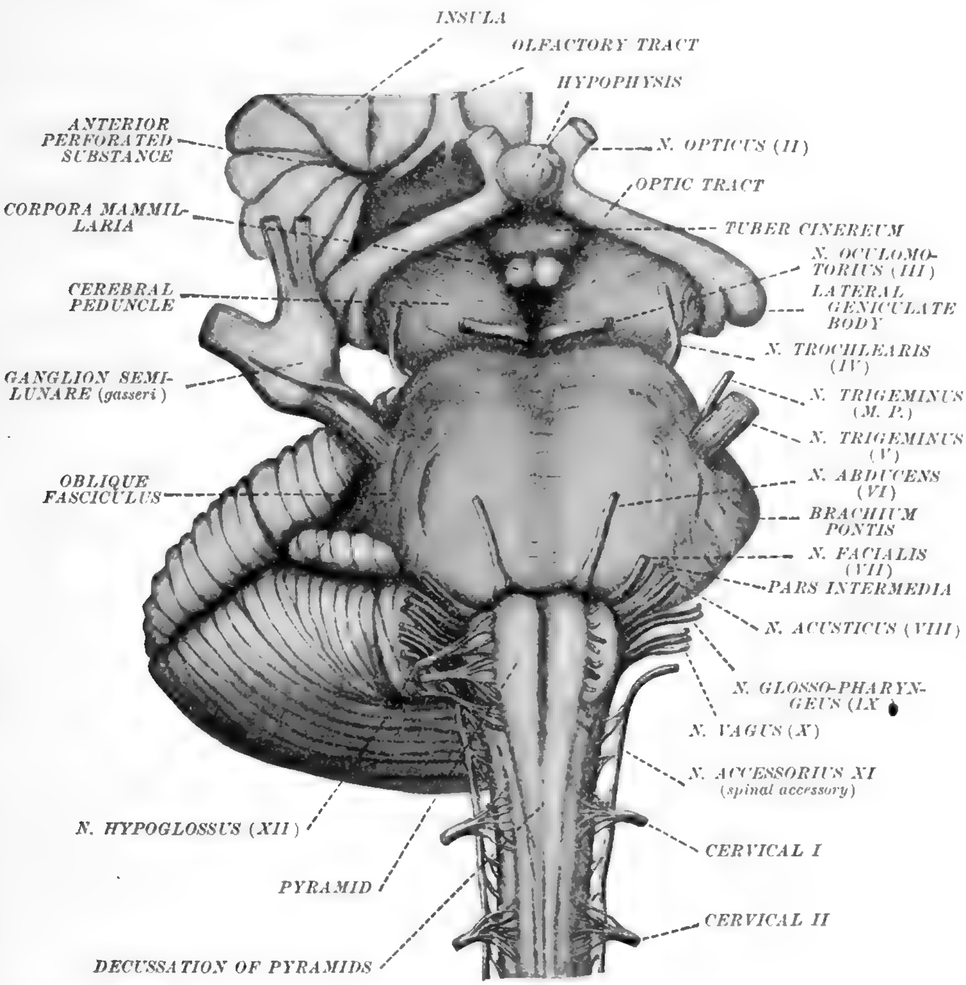
THE MEDULLA OBLONGATA

The **medulla oblongata** is the upward continuation of the spinal cord. It is only about 25 mm. long, extending from just above the first cervical nerve (beginning of the first cervical segment of the spinal cord) to the inferior border of the pons. It lies almost wholly within the cranial cavity, resting upon the superior surface of the basal portion of the occipital bone, with its lower extremity in the foramen magnum. Its weight is from 6 to 7 gm. or about one-half of one per cent. of the whole cerebro-spinal axis. It is a continuation of the spinal cord and more—it contains structures continuous with and homologous to the structures of the spinal cord, and in addition it contains structures which have no homologues in the spinal cord. Due in part to these additional structures, the medulla, as it approaches the pons, rapidly expands in both its dorso-ventral and especially in its lateral diameters. With it are associated seven of the twelve pairs of cranial nerves.

On its anterior or **ventral aspect** the anterior median fissure of the spinal cord becomes broader and deeper because of the great height attained by the **pyramids.** At the level at which the pyramids emerge from the pons, the region in which they are largest, the fissure terminates in a triangular recess so deep as to merit the name **foramen cæcum.** The pyramids are the great descending cerebral or motor funiculi. In the medulla oblongata they decrease in bulk in passing towards the spinal cord, for the reason that many of the pyramidal axones are contributed to structures of the medulla. At the lower end of the medulla occurs the **decussation of the pyramids,** by which the anterior median fissure is almost obliterated for about

6 mm., and which, upon removal of the pia mater, may be easily observed as bundles of fibres interdigitating obliquely across the mid-line. Not all the pyramidal fibres cross to the opposite side at this level in man, but a portion of those coursing in the lateral periphery of the medulla maintain their ventro-mesial position and continue directly into the spinal cord, to form there the ventral cerebro-spinal fasciculus or direct pyramidal tract. However, most of such fibres finally cross the mid-line during their course in the spinal cord. The exact proportion of the direct fibres is variable, but always the greater mass of each pyramid crosses to the opposite side at the level of the decussation of the pyramids, and descends the cord as the lateral

FIG. 580.—SEMI-DIAGRAMMATIC REPRESENTATION OF THE VENTRAL ASPECT OF THE RHOMBENCEPHALON AND ADJACENT PORTIONS OF THE CEREBRUM. (Modified from Quain.)



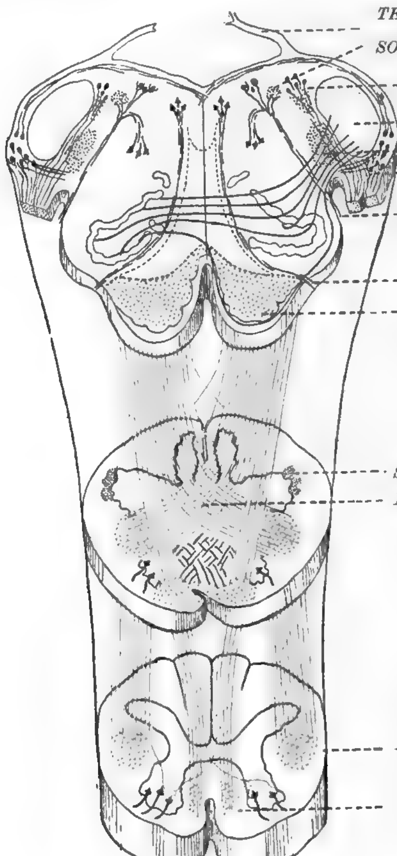
cerebro-spinal fasciculus or crossed pyramidal tract. Both of these pyramidal tracts are described in the discussion of the fasciculi of the cord.

Each pyramid is bounded laterally by the **antero-lateral sulcus,** also continuous with that of the same name in the spinal cord. Towards the pons this sulcus separates the pyramid from the **olive** (inferior olivary nucleus), and in the region of the olive there emerge along this sulcus the root filaments of the hypoglossal nerve. These are in line with the filaments of the ventral roots of the spinal nerves. The olives, as their name implies, are oblong oval eminences about 1·2 cm. in length. They extend to the border of the pons, and are somewhat thicker at their upper ends. Their surfaces are usually smooth, except at their lower ends, where they frequently

appear ribbed, owing to bundles of the **external arcuate fibres** passing across them to and from the *restiform* body, which occupies the extreme lateral portion of the medulla. Along the line between the restiform body and the olives are attached the root filaments of the *vagus, glosso-pharyngeal,* and *spinal accessory nerves.* Both the *abducens* and the *facial* nerve emerge along the border of the pons, the facial in line with the glosso-pharyngeal, but the abducens in line with the hypoglossus.

Dorsal aspect.—The increased lateral diameter of the medulla oblongata is contributed to a great extent by the **restiform bodies.** These are the inferior cerebellar peduncles, and contain the majority of both the ascending and the descending fibres, which connect the cerebellum with the structures below it. In toto, the restiform bodies are much larger than could be formed by the combined cerebellar

Fig. 581.—Diagram Showing the Decussation of the Pyramids.
The uppermost level represented is near the inferior border of the pons.



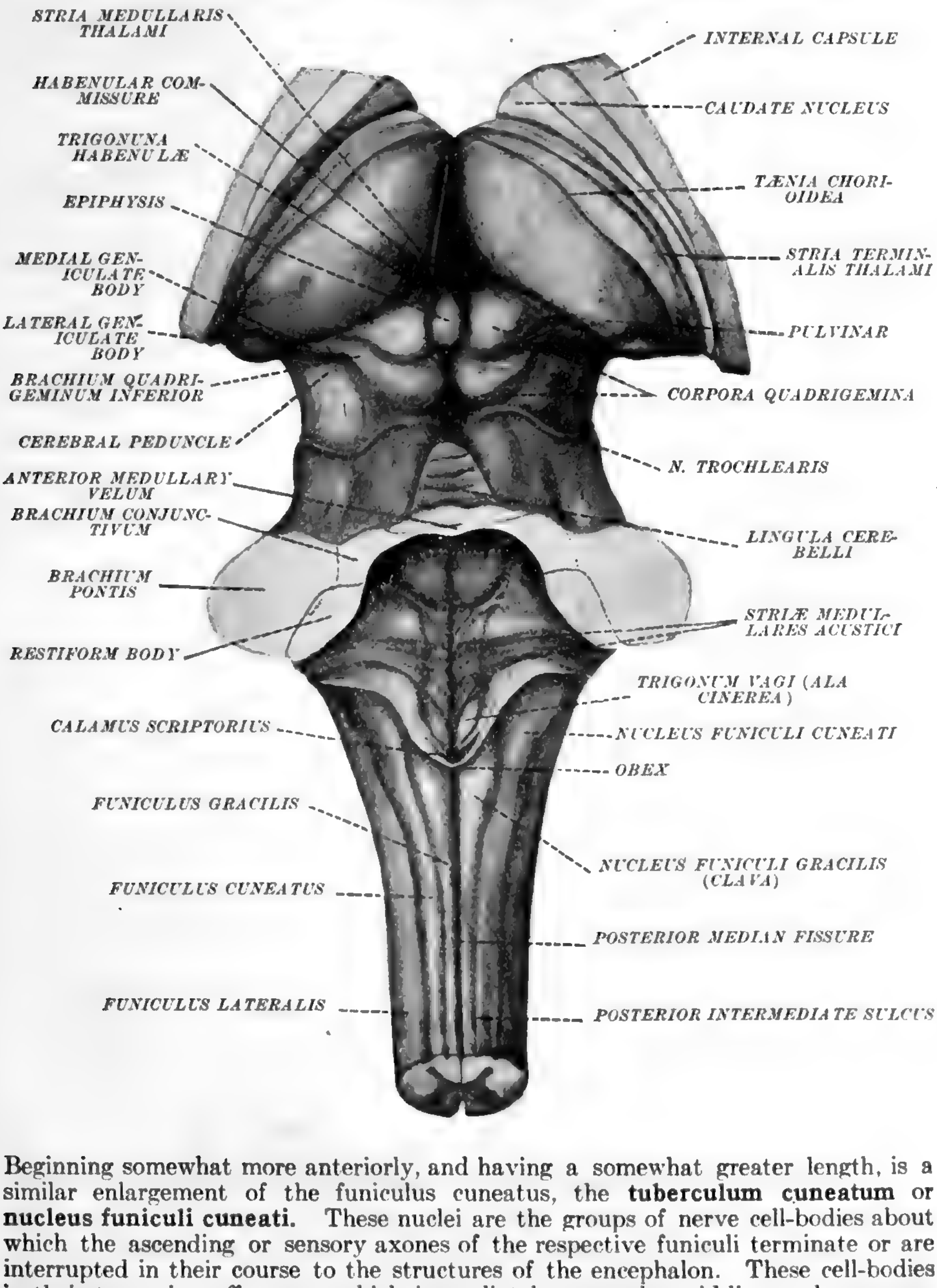
fasciculi of the spinal cord, their great size being due to their receiving numerous axones coursing in both directions, which connect the cerebellum with structures contained in the medulla oblongata alone, so that in the medulla they increase as they approach the cerebellum. Their name (*restiform* meaning rope-like) was suggested from the appearance frequently given them by the fibres of the cochlear (acoustic) division of the eighth cranial nerve, which course around their lateral periphery to become the *striæ medullares acustici* in the floor of the fourth ventricle.

Upon removal of the cerebellum it may be seen that below the *calamus scriptorius* (inferior terminus of the fourth ventricle) the structures manifest in the dorsal surface of the medulla are directly continuous with those of the spinal cord. The fasciculus gracilis (Goll's column) of the spinal cord acquires a greater height and volume and becomes the **funiculus gracilis** of the medulla, and because of this

increased height the posterior median sulcus of the cord becomes deepened into the **posterior median fissure.** The posterior intermediate sulcus is also accentuated by Burdach's column, likewise enlarged into the **funiculus cuneatus** of the medulla. The lateral funiculus of the medulla, of course, does not contain the lateral or crossed pyramidal tract present in the spinal cord.

At the border of the calamus scriptorius the funiculus gracilis terminates in a slight elevation, the **clava,** which is the superficial indication of the *nucleus funiculi gracilis.*

Fig. 582.—Dorsal Aspect of Medulla Oblongata and Mesencephalon, Showing the Floor of the Fourth Ventricle (Rhomboid Fossa). (Modified from Spalteholz.)

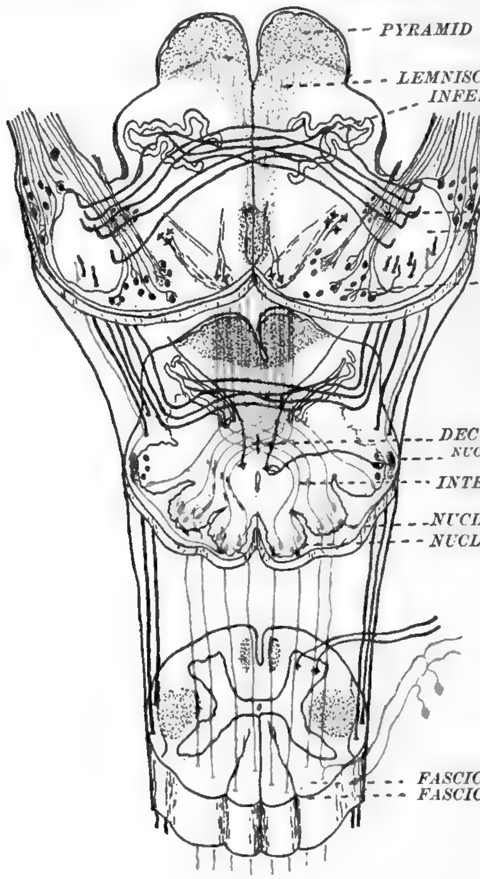


Beginning somewhat more anteriorly, and having a somewhat greater length, is a similar enlargement of the funiculus cuneatus, the **tuberculum cuneatum** or **nucleus funiculi cuneati.** These nuclei are the groups of nerve cell-bodies about which the ascending or sensory axones of the respective funiculi terminate or are interrupted in their course to the structures of the encephalon. These cell-bodies in their turn give off axones which immediately cross the mid-line and assume a more ventral position, contributing largely to the *lemniscus* or fillet of the opposite

side, and thus such axones are the encephalic continuation of the central sensory pathway conveying impulses from the periphery of one side of the body to the opposite side of the cerebrum. The crossing of these axones is known as the *decussation of the lemnisci.*

With the termination of the dorsal funiculi and the ventral course of the fibres of the lemnisci in their decussation, the central canal of the spinal cord loses its roof of nervous tissue in the medulla and comes to the surface as the fourth ventricle.

Fig. 583.—Diagram of the Decussation of the Lemnisci.



The floor of the fourth ventricle, which corresponds to the floor of the central canal, is considerably widened into two **lateral recesses** opposite the junction of the cerebellar peduncles of either side, and, being pointed at both its superior and inferior extremities, it is rhomboidal in shape and thus is the **fossa rhomboidea.** The pia mater of the spinal cord is maintained across the tip of the calamus scriptorius to form the **obex,** a small, non-nervous, semilunar lamina roofing over the immediate opening of the central canal.

THE PONS

The *pons* (*Varolii*) is, for the most part, a great commissure or 'bridge' of white substance coursing about the ventral aspect of the brain-stem, and connecting the cerebellar hemisphere of one side with that of the other. In addition it contains fibres passing both to and from the structures of the brain-stem and the grey substance of the cerebellum. Each of its lateral halves forms the middle of the three cerebellar peduncles, the *brachium pontis*.

In size it naturally varies directly with the development of the cerebellum, both in a given animal and relatively throughout the animal series. In man it attains its

greatest relative size, and possesses a mediam or *basilar sulcus* in which lies the basilar artery. Its sagittal dimension varies from 25 to 30 mm., while its transverse dimension (longitudinal with the course of its fibres) is somewhat greater. It is a rounded white prominence interposed between the cerebral peduncles (crura) above and the medulla oblongata below. Its *inferior margin* is rounded to form the **inferior pontine sulcus,** which, between the points of the emergence of the pyramids, is continuous with and transverse to the foramen cæcum. Its *superior margin* is thicker and is rounded to form the **superior pontine sulcus,** which, between the cerebral peduncles, is continuous with and transverse to the interpeduncular fossa. It is bilaterally symmetrical. The ventro-lateral bulgings of its sides (and, therefore, the basilar sulcus) are produced by the passage through it of the fibres of the cerebral peduncles from above, to reappear as the pyramids below. Its ventral surface rests upon the basilar process of the occipital bone and the dorsum sellæ of the sphenoid, while its lateral surfaces are adjacent to the posterior parts of the petrous portions of the temporal bones.

The fibres of the thicker superior portion of the brachium pontis course obliquely downwards to their entrance into the cerebellar hemisphere; those of the lower and mid-portions course more transversely, naturally converging upon approaching the cerebellum. Certain fibres of the upper mid-portion course at first transversely and then turn abruptly downwards across the fibres above them, to join the inferior portion of the brachium pontis. This bundle is termed the **oblique fasciculus** (fig. 580). The *trigeminus* or fifth cranial nerve penetrates the superior lateral portion of each brachium pontis near the point of the downward turn of the oblique fasciculus; its large afferent and its small efferent roots accompany each other quite closely.

That portion of the rhombencephalon overlying the pons and forming the floor of the fourth ventricle is not a part of the pons at all. It is merely a continuation of the brain-stem from the medulla below to the structures above. Therefore on the *dorsal surface* there is no line of demarcation between the pons and medulla below or between the pons and isthmus above. The fibres of the trigeminus pass through the pontine fibres to and from their nuclei in the brain-stem.

THE CEREBELLUM

The **cerebellum** or *hind brain* is the largest portion of the rhombencephalon. It lies in the posterior or cerebellar fossa of the cranium, and behind the pons and medulla oblongata, overhanging the latter. It fits under the occipital lobes of the cerebral hemispheres, from which it is separated by a strong duplication of the inner layer of the dura mater, the *tentorium cerebelli.* Its greatest diameter lies transversely, and its average weight, exclusive of the dura mater, is about 140 gm., or about 10 per cent. of the entire encephalon. It varies in development with the cerebrum, and, like it, averages larger in the male. It is relatively larger in adults than in children. Its development begins as a thickening of the anterior portion of the roof (dorsal zone) of the posterior of the three primary brain vesicles. Resting upon the brain-stem, it roofs over the fourth ventricle and is connected with the structures anterior, below, and posterior to it by its three pairs of peduncles.

The surface of the cerebellum is thrown into numerous narrow **folia** or *laminæ*, which in the given localities run more or less parallel with each other. They are separated by narrow but relatively deep **sulci.** Unlike the spinal cord and medulla, in which the grey substance is centrally placed and surrounded by a mantle of white substance, the surface of the cerebellum is itself a cortex of grey substance, the *cortical substance,* enclosing a core of white substance, the *medullary* body. However, within this central core of white substance are situated definite grey masses, the *nuclei* of the cerebellum.

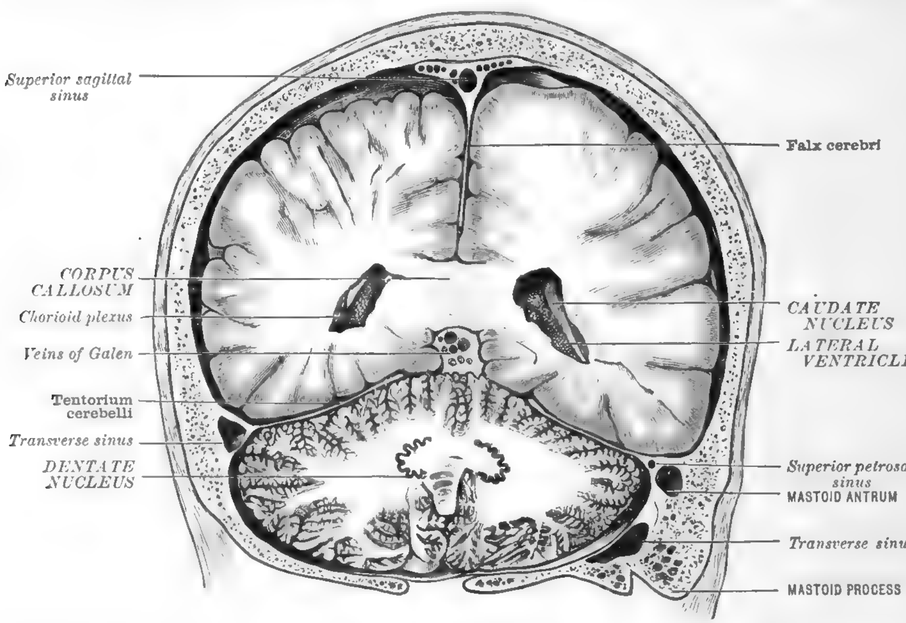
The **gross divisions** of the cerebellum are three: the two larger lateral portions, the **hemispheres,** and between these the smaller central portion, the **vermis.** The demarcation between these gross divisions is not very evident from the dorsal surface, because the hemispheres in their extraordinary development in man encroach upon the vermis, and, being pressed under the overlapping cerebral hemispheres, they become partially fused upon the vermis along the dorsal mid-line. Though differentiated simultaneously with the cerebellar hemispheres in the human fœtus,

in most of the mammalia the vermis is the largest and most evident of the parts, and it is practically the only part which exists in the fishes, reptiles, and birds. In man, owing to the fact that the vermis does not keep pace in development with the hemispheres, there results a very decided notch between the two hemispheres along the line of the entire ventral and inferior aspect of the cerebellum, the floor of this notch being the surface of the vermis. The inferior portion of the notch is the **posterior cerebellar notch** (**incisura marsupialis**); its prolongation above is wider than below, and is termed the **superior cerebellar notch.** It is occupied by a fold of the dura mater, the falx cerebelli. With the variations in contour of the cerebellum, certain of its sulci are broader and deeper, and merit the name **fissures.** These are more or less definitely placed, and subdivide the hemispheres into **lobes** and the vermis (the median lobe) into **lobules.**

Dorsal surface.—The dorsal surface is bounded from the inferior and ventral surface by the **horizontal fissure,** coursing along the inferior borders of the cerebellar hemispheres. Between this and the extreme anterior border are two other fissures, the **posterior** and **anterior semilunar fissures.** These, like the horizontal

FIG. 584.—SECTION OF HEAD PASSING THROUGH THE MASTOID PROCESSES OF THE TEMPORAL BONES AND BEHIND THE MEDULLA OBLONGATA. SHOWING THE POSITION OF THE CEREBELLUM.

(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)



fissure, may be traced, with slight interruptions, across the mid-line, and consequently mark off not only the two hemispheres but also the vermis into corresponding divisions.

The **superior semilunar lobe** (postero-superior lobe) of each hemisphere lies between the horizontal and the posterior semilunar fissures. It largely composes the inferior border of the cerebellum, and, therefore, is the longest of the lobes.

The remaining dorsal surface of the hemispheres, because of the frequently less complete development of the anterior semilunar fissure, is sometimes referred to as the **quadrangular lobe,** with its *posterior* and its *anterior portions*. On the other hand, especially when the anterior semilunar fissure is well marked, this area may be divided into—(1) the *posterior semilunar lobe,* between the posterior and anterior semilunar fissures, and (2) the *anterior semilunar lobe,* anterior to the anterior semilunar fissure.

The dorsal aspect of the vermis, the **superior vermis,** because of the fusion of the hemispheres, is, for the most part, a slight ridge, the **monticulus,** instead of a depression. However, in the inferior portion of the dorsal surface the depression

of the posterior notch begins, and here the horizontal and the posterior semilunar fissures approach each other so closely that the corresponding subdivision of the vermis is seldom more than a single folium, the **folium vermis** (*cacuminis*).

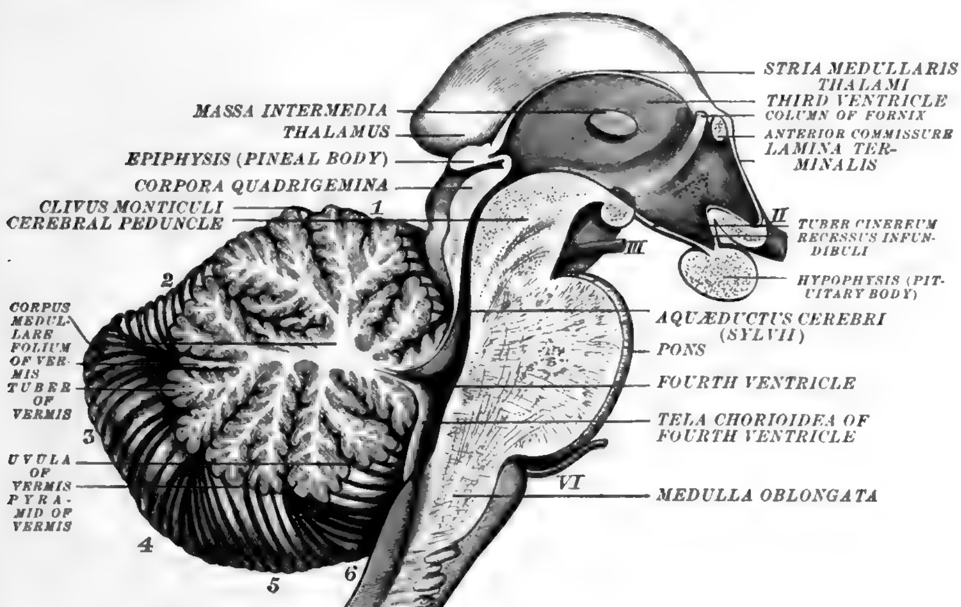
The monticulus proper is divided into an inferior lobule, the **clivus,** and a superior lobule, the **culmen.** These appear as continuations across the mid-line of the posterior and anterior crescentic lobes of the hemispheres, and are separated by the corresponding fissures.

At the extreme anterior part of the dorsal surface and in the bottom of the anterior cerebellar notch lies a more definitely defined portion of the vermis. This is the **central lobule** (lobe). It is broadened laterally into two pointed wings, the *alæ* of the central lobule, the folia of which, if present, are parallel with those of the anterior semilunar lobes.

If the anterior margin of the central lobule be lifted, the **lingula cerebelli** (*lingula vermis*) will appear. It is a thin, tongue-like anterior projection of the cortical substance upon the *anterior medullary velum,* the roof of the superior portion of the fourth ventricle.

Fig. 585.—Median Section Through Cerebellum and Brain-stem. (Allen Thompson, after Reichert.)

1, culmen monticuli; 2, superior semilunar lobe; 3, inferior semilunar lobe; 4, slender lobe; 5, biventral lobe; 6, tonsil.



Ventral surface.—The three cerebellar peduncles of each side join to form a single mass of white substance, and enter the ventral aspect of each hemisphere at the inner and ventral extremity of the horizontal fissure. The ventral and inferior surface of the cerebellum is less convex than the dorsal surface. The hemispheres are decidedly separated by a continuation of the posterior cerebellar notch, which becomes broader and contains the inferior portion of the vermis, **vermis inferior,** and whose margins embrace the medulla oblongata. The ventral surfaces of the hemispheres are each divided by the intervening fissures into four lobes.

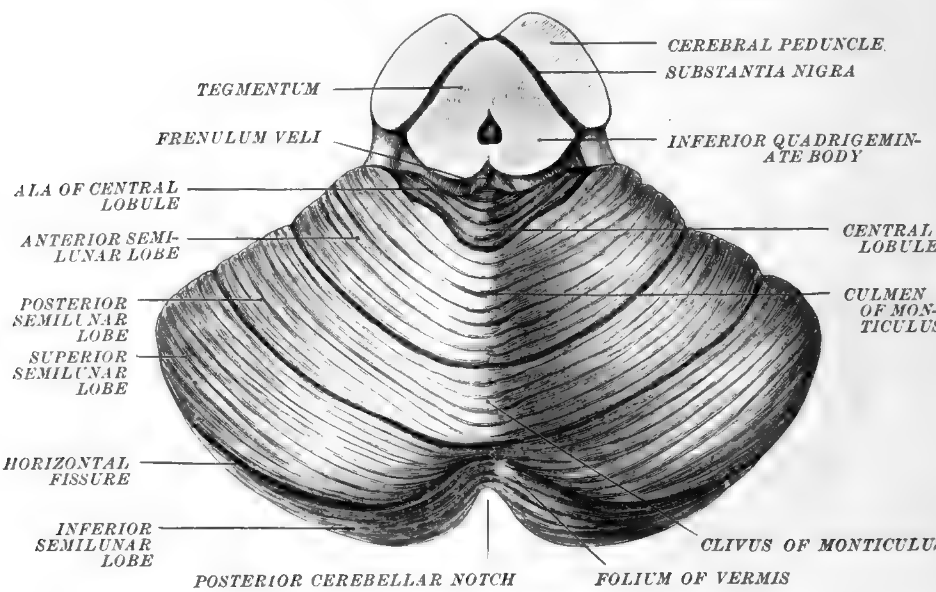
Below, the **inferior semilunar lobe** (postero-inferior lobe) is separated from the superior semilunar lobe of the dorsal surface by the horizontal fissure. It is the largest of the ventral lobes, and is broader at its medial extremity. Frequently two and sometimes three of its curved sulci appear deeper than others, and separate it into two or three slender lobules, **lobuli graciles.** More commonly there are two of these, the *lobulus gracilis posterior* and *lobulus gracilis anterior,* separated by sulci (fissures) correspondingly named.

The **biventral lobe** is smaller and more curved than the inferior semilunar lobe, from the anterior margin of which it is separated by the curved **parapyramidal fissure.** Its inner extremity is pointed and does not extend to the vermis; its outer extremity is broader and curves anteriorly to the inner and ventral extremity of the horizontal fissure—the line of outer termination of the inferior semilunar lobe.

The **tonsil** (*amygdala*) is a rounded, triangular mass, placed mesially within the inner curvature of the biventral lobe, and separated from it by the **retrotonsillar fissure.** Its mesial border slightly overlaps the vermis.

The smallest of the lobes is the **flocculus.** It lies adjacent to the inferior and lateral surface of the mass of white substance produced by the confluence of the cerebellar peduncles, and extends into the inner extremity of the horizontal fissure. It is so flattened that its short folia give it the appearance suggesting its name. Occasionally there is added a second, less perfectly formed portion, the *secondary flocculus.* From each floccular lobe there passes towards the mid-line a thin band of white substance, the **peduncle of the flocculus;** these extend to meet each other at the most anterior portion of the inferior vermis, and thus form the narrow **posterior medullary velum.**

Fig. 586.—Diagram of the Dorsal Surface of the Cerebellum.



The **inferior vermis** is more definitely demarcated than the superior. Lying in the floor of the inferior notch, it is separated on each side from the adjacent lobes of the hemispheres by a well-marked sulcus, the **vallecula cerebelli.** By contour and by deeper transverse fissures (sulci) occurring at intervals across it, four divisions or lobules of the inferior vermis are recognised. These lobules, like those of the superior vermis, are each in intimate relation with the pair of lobes of the hemispheres adjacent to it on either side.

1. The **tuber vermis** is adjacent to the folium vermis of the dorsal aspect, and thus is the most inferior lobule of the inferior vermis. It is a short, somewhat pyramidal-shaped division, whose four or five transversely arranged folia are continuous with the folia of the inferior crescentic lobes on either side.

2. The **pyramid** is separated from the tuber vermis by the **post-pyramidal fissure.** Its several folia cross the vallecula cerebelli and curve to connect with the biventral lobes on either side.

3. The **uvula** is separated from the pyramid by the **prepyramidal fissure.** It is triangular in shape. Its base or broader inferior portion appears as two laterally projecting ridges of grey substance, the **furrowed bands,** which extend across the floor of the vallecula and under the mesial margins of the tonsils on either side. In

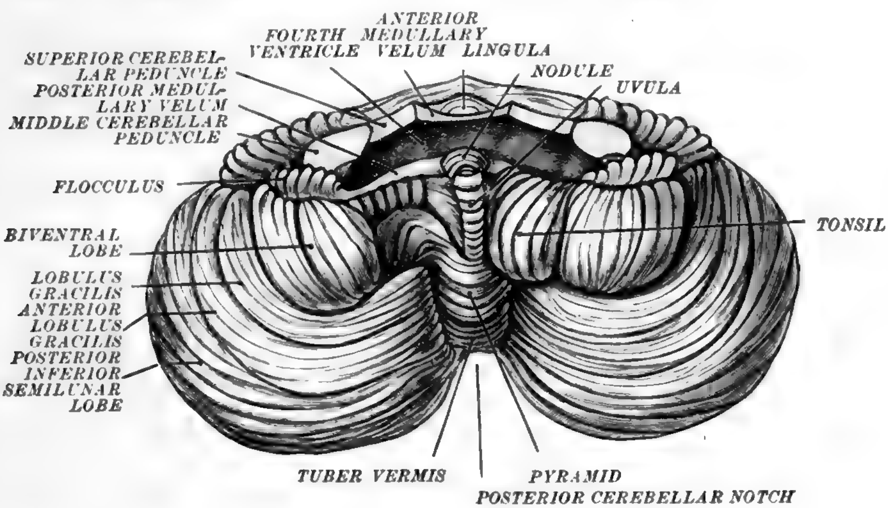
these bands its folia curve and become continuous with the tonsils. The uvula and the two tonsils are sometimes referred to collectively as the *uvular lobe*.

4. The **nodule** is the smallest and most anterior division of the inferior vermis. It is separated from the uvula by the **post-nodular fissure,** and is closely associated anteriorly with the posterior medullary velum, the transverse continuation of the peduncles of the floccular lobes.

Internal structure of the cerebellum.—The white substance of the cerebellum is continuous with its peduncles and forms a compact central mass. Over the surface of this the grey substance or cortex is spread in a thin but uniform layer. Upon section of the cerebellum certain of the sulci as well as the fissures are shown to be much deeper than is apparent from the surface. The deeper sulci separate the lobes into divisions, the **medullary laminæ,** each of which is composed of a number of folia and each of which has its own core of white substance. The folia of the laminæ line the sulci (and fissures), and also comprise their surface aspect, and are separated by the shallow, secondary sulci. The larger laminæ are subdivided into from two to four secondary laminæ of varying size. Such subdivision is especially marked in the vermis. Here each lamina comprises a lobule and is, therefore, separated by

Fig. 587.—Diagram of the Ventral and Inferior Surface of the Cerebellum after the Removal of the Medulla Oblongata, Pons, and Mesencephalon.

The tonsil of the right side is omitted in order to display the connection of the pyramid with the biventral lobe, the furrowed band of the uvula, and more fully the posterior medullary velum. The anterior notch is less evident than in the actual specimen.



a fissure, and each lobule is usually subdivided with the exception of the nodule, the folium, and the lingula. In sagittal sections, or sections transverse to the general direction of the sulci, this arrangement of the laminæ gives a foliate appearance, which, especially in sagittal sections of the vermis, is termed the **'arbor vitæ.'**

The **cerebellar cortex** consists of three layers and contains four general types of cell-bodies of neurones, all of which possess features peculiar to the cerebellum.

The outermost or **molecular layer** contains small **stellate cells** with relatively long dendrites. These serve to associate the different portions of a given folium. The axones of the largest of them give off branches which form pericellular baskets about the bodies of the *cells of Purkinje*, each axone contributing to several baskets. The **layer of Purkinje cells,** or the middle layer, is quite thin. The bodies of the cells of Purkinje are arranged in a single layer, and their elaborate systems of dendrites extend throughout and largely compose the molecular layer. The dendrites of these, the most essential cells of the cortex, are displayed in the form of arborescent fans (see fig. 555), arranged parallel with each other and transverse to the long axis of the folium containing them. Their axones are given off from the base of the cell-body, acquire their medullary sheaths quite close to the cell-body, and, after giving off several collaterals in the inner layer, pass into the general white substance and thence to other laminæ or lobes and certain of them to structures outside the cerebellum. The inner layer is the **granular layer.** It contains numerous small nerve-cells or granule-cells which possess from two to five radiating dendrites, unbranched except at their termination, which occurs suddenly in the form of three to six claw-like twigs. Their axones are given off either from the cell-body direct or more often

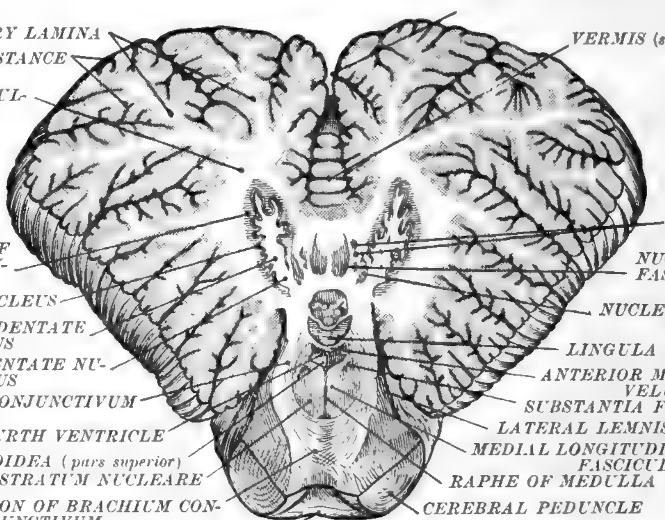
from the base of one of the dendrites, and pass outwards into the molecular layer, where they bifurcate and course in both directions parallel to the long axis of the folium, to become associated with the dendrites of the cells of Purkinje. In the layer of the cells of Purkinje there is situated at intervals a neurone of the Golgi type II (see fig. 555). The short, elaborately branched axone of this neurone is distributed among the cells of the granular layer. Axones conveying impulses to the cerebellar cortex terminate in the granular layer as '*moss fibres*,' or directly upon the cells of Purkinje as '*climbing fibres*,' and probably upon the cells of the Golgi type II.

Thus the neurones which receive impulses coming to the cortex are the cells of Purkinje, probably the Golgi cells of type II, and the granule-cells; those which distribute these impulses to other neurones of the folium are the Golgi cells of type II, the granule-cells, and the basket-cells (association neurones), and the collaterals of the cells of Purkinje. Impulses are conveyed from the cortex of a folium to that of other folia, lamina, lobules or lobes, or to the nuclei of the cerebellum, or to structures outside the cerebellum by the axones of the cells of Purkinje.

The **nuclei of the cerebellum** are in its central core of white substance. They are four in number, and all are paired, those of each pair being situated opposite each other on either side of the mid-line.

1. The largest of them is the **dentate nucleus.** This is an isolated mass of grey substance situated in the core of white substance of each hemisphere. It is in the form of a folded or corrugated cup-shaped lamina, with the opening of the cup

Fig. 588.—Section of Cerebellum and Brain-stem Passing Obliquely Through Inferior Portion of Cerebellum to Anterior Margin of Pons. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



(*hilus*) directed anteriorly and obliquely inwards. It contains a mass of white substance and possesses a capsule.

2. The **nucleus emboliformis** is an oblong and much smaller mass of grey substance, which lies immediately internal to the hilus of the dentate nucleus. It is probably of the same significance as the dentate nucleus, being merely a portion separated from it.

3. The **nucleus globosus,** the smallest of the cerebellar nuclei, is an irregular horizontal mass of grey substance with its larger end placed in front. It lies close to the inner side of the nucleus emboliformis, and often appears separated into two or more rounded or globular masses.

4. The **nucleus fastigii** (roof nucleus) is the second largest of the cerebellar nuclei, and is the most mesially placed. The pair is situated in the roof of the fourth ventricle, and so near the mid-line that both nuclei are in the white substance of the vermis. They are ovoid in shape, and the nucleus of one side receives axones from the nucleus of the vestibular division of the eighth cranial nerve chiefly of the opposite side, the decussation of these axones taking place in the vermis. Its cells are larger than those of the two first-mentioned nuclei.

The peduncles of the cerebellum.—The peduncles consist of three pairs—the

inferior, middle, and superior. The three peduncles of each side come together at the level of the lower border of the pons, and the entering and emerging fibres of which they are composed become continuous with the central core of white substance of the cerebellar hemispheres.

The **restiform body** of the medulla oblongata is the inferior peduncle. It forms the lateral boundary of the inferior portion of the fourth ventricle, and upon reaching the level of the pons turns sharply backwards into the cerebellum. In the region of the turn it is encircled externally by fibres of the cochlear division of the eighth cranial nerve. It contains fibres, both ascending and descending, between the cerebellar cortex and the structures below the cerebellum:—(1) Fibres from the spinal cord including the lateral cerebello-spinal fasciculus (direct cerebellar tract) and probably a small proportion of the ascending fibres of the antero-lateral superficial fasciculus (Gowers' tract); (2) fibres from the olive of the same and opposite side of the medulla oblongata; (3) fibres from the nuclei of the funiculus gracilis and cuneatus of the same and opposite sides; (4) fibres to the olive of the opposite side; (5) fibres to the nuclei of the motor cranial nerves; (6) fibres descending to the ventral horn cells of the spinal cord. The ascending or afferent fibres of the cerebello-spinal and cerebello-olivary fasciculi are the principal components of the inferior peduncle. Of these, the fibres of the direct cerebellar tract terminate in the cortex of the superior vermis of both sides of the mid-line, but, for the most part, in that of the opposite side. The olivary fibres end in the cortex of both the superior vermis and the adjacent cortex of the hemispheres, and some of them terminate in the nucleus dentatus.

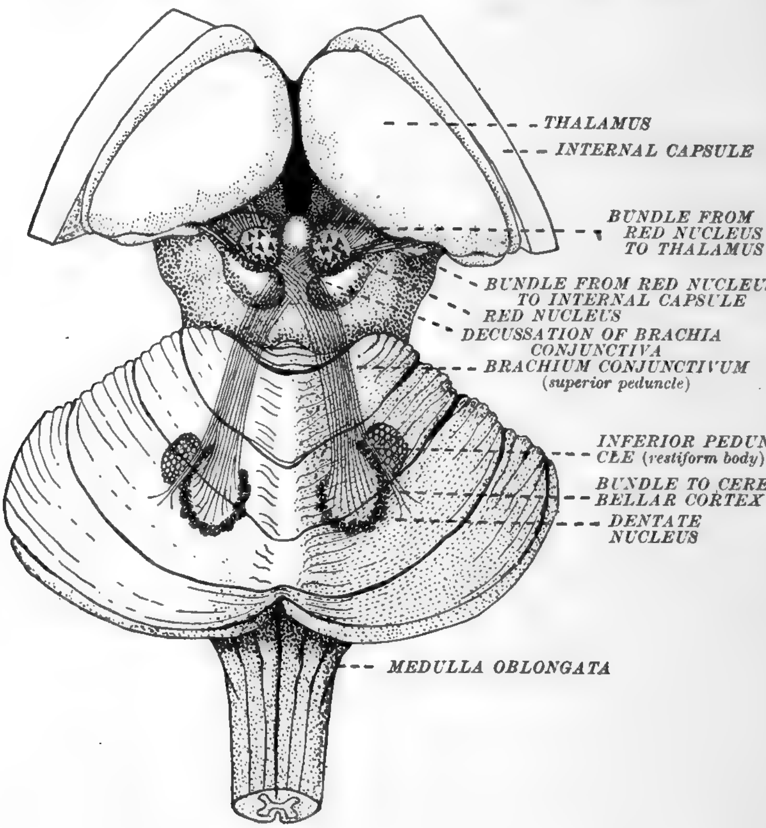
The **brachium pontis** or the middle peduncle is the largest of the three cerebellar peduncles. In it the pons fibres pass slightly downwards and into the cerebellar hemisphere, between the lips of the anterior part of the horizontal fissure, entering at the outer side of the inferior peduncle. It consists of the transverse fibres of the pons, and within the cerebellum its fibres are distributed in two main groups—the upper transverse fibres of the pons apparently pass downwards to radiate in the lower portion of the hemisphere, while the lower transverse fibres pass upwards and inwards to radiate in the superior part of the hemisphere and vermis. For the most part the fibres of the middle peduncle may be considered as commissural fibres, passing from one side of the cerebellum to the other. Each peduncle contains fibres coursing in opposite directions. Many of these fibres are interrupted in their course to the opposite side by cells scattered throughout the pons, *nuclei pontis*, and, therefore, in each brachium pontis some of the fibres are processes of the cells of the cerebellum and course towards the opposite side, while others are processes of the cells of the pontine nuclei and course to the cerebellar hemisphere of the same side. Furthermore, there are evidences after degeneration that the brachium pontis also contains a few fibres from the cerebellum to the structures of the brain-stem and spinal cord.

The **brachium conjunctivum** or superior cerebellar peduncle emerges from the cerebellum on the inner side of the brachium pontis. It also extends on the mesial side of the course of the restiform body. It forms the lateral boundary of the superior portion of the fourth ventricle. Its transverse section appears semilunar in shape, with the concave side next to the cavity of the ventricle. The dorsal border which inclines towards the mid-line is connected with that of the corresponding peduncle of the opposite side by the *anterior medullary velum*, which thus roofs over the superior part of the fourth ventricle. The ventral border is distinguished from the pons by an open furrow or sulcus.

The superior cerebellar peduncles are almost entirely efferent pathways as to the cerebellum, and form the chief connections between the cerebellum and the cerebrum. They arise almost wholly from the dentate nuclei. As they course forwards they slightly converge and disappear under the inferior quadrigeminate bodies. Here, in the tegmentum of the mesencephalon, they undergo an almost total **decussation,** and then the majority of the fibres of each peduncle, having thus crossed the mid-line, terminate in the *red nucleus* of the opposite side. The red nucleus lies in the tegmentum of the mesencephalon, below the superior quadrigeminate bodies, and therefore quite close to the decussation. The cells of the red nucleus, about which the fibres of the peduncle terminate, in their turn send processes (axones) into the prosencephalon, most of which enter the thalamus, but some pass under the thalamus to join the internal capsule.

In addition to the fibres having the origin and course described above, and which constitute the greater mass of the superior cerebellar peduncle, each peduncle is said to contain fibres which—(1) arise in the cerebellar cortex of the same and opposite sides of the mid-line, instead of from the dentate nucleus, and which join the peduncle at the side of the dentate nucleus, between it and the restiform body; (2) fibres which do not cross the mid-line in the decussation, but terminate in the red nucleus of the same side; (3) possibly some fibres are not interrupted in the red nucleus, but pass directly into the thalamus; (4) a small proportion of fibres afferent as to the cerebellum, which arise in the structures of the cerebrum and pass in to the cerebellum; and (5) the greater part, if not all, of the ascending fibres of the antero-lateral superficial fasciculus (Gowers' tract) of the spinal cord. The latter, instead of entering the cerebellum by way of the restiform body, are deflected in the medulla

Fig. 589.—Transparency Drawing Showing the Origin, Course, and Connections of the Superior Cerebellar Peduncles (Brachia Conjunctiva) in the Formation of 'Stilling's Scissors.'



and pass in the lateral tegmentum of the pons to the anterior medullary velum, where they turn backwards to enter the cerebellum in its superior peduncle and pass to its cortex, probably from the outer side of the dentate nucleus (see fig. 605).

The anatomy of the fourth ventricle.—The fourth ventricle is rhomboidal in shape, being considerably widened at the level of the brachia pontis and pointed at each end. Its floor consists of a slight depression in the brain-stem, the *fossa rhomboidea*, and corresponds to the floor of the central canal. Its pointed inferior end, the *calamus scriptorius*, is directly continuous with the central canal, and its narrowed anterior end is continued into the aquæductus cerebri (Sylvii) of the mesencephalon, which is nothing more than a resumption of the tubular form of the canal. The entire cavity of the ventricle is lined with an epithelium which is continuous with the epithelium, or ependyma, of the central canal.

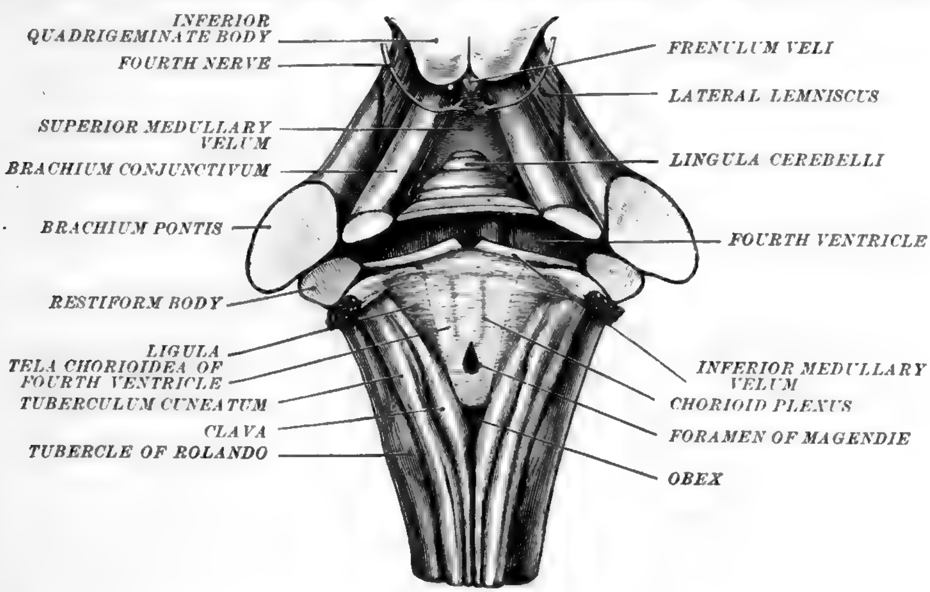
The *roof of the anterior portion* of the fourth ventricle is nervous, consisting of a

thin lamina of white substance, the *anterior medullary velum*, thickened at the sides by the brachia conjunctiva. At its extreme mesencephalic end the anterior medullary velum is slightly thickened by a continuation of the white substance of the inferior quadrigeminate bodies, forming the **frenulum veli.** The inferior portion of the velum is continuous with the white substance of the cerebellum, and is covered by the lingula cerebelli, an extension of the cortical substance of the superior vermis (fig. 582).

The *roof of the middle portion* of the fourth ventricle is formed by the cerebellum proper, the vermis and the mesial portions of the hemispheres. The nervous portion of the roof terminates with the *posterior medullary velum*, a thin, narrow band of white substance which is the continuation of the peduncles of the floccular lobes, and which connects them at the mid-line with the nodule of the inferior vermis.

The *roof of the inferior portion* of the fourth ventricle is non-nervous. It is the **tela chorioidea** of the fourth ventricle, a semilunar lamina consisting of the epithelial lining of the ventricle, reinforced by a continuation of the connective tissue of the pia mater and the adjacent portion of the arachnoid. Along the line of its attachment to the surface of the medulla it is thickened, and in sections this portion bears the name **ligula** (*tænia ventriculi quarti*). The thickened portion spanning the tip of

Fig. 590.—Diagram of the Roof and Lateral Boundaries of the Fourth Ventricle.



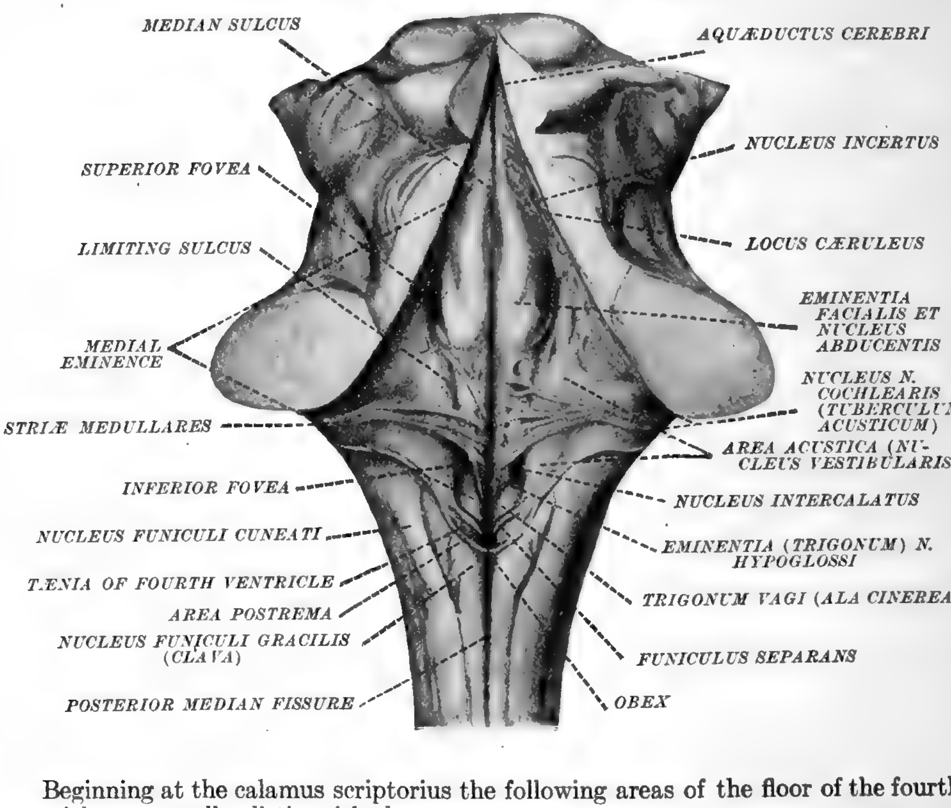
the calamus scriptorius is termed the **obex.** The width of the ventricular cavity is extended outwards from its widest part into the *lateral recesses*, narrow pockets on each side and around the upper parts of the restiform bodies. In the mid-line of the lower part of the tela chorioidea there is a more or less well-marked opening, the *foramen of Magendie* (medial aperture of the fourth ventricle), which is a lymph-channel connecting the cavity of the ventricle with the subarachnoid space. There is a similar opening from each lateral recess (*lateral apertures*).

The *chorioid plexuses* of the fourth ventricle consist of highly vascular, lobular, villus-like processes of the ventricular surface (pia mater) of the tela chorioidea. They are reddish in the fresh specimen, and the epithelial lining of the ventricle is closely adapted to the unevennesses of their surfaces. From below they run as two parallel masses on either side of the mid-line, which become united above, and then are separated again into two lateral processes which bend at right angles and project into the lateral recesses. Portions frequently protrude through the three openings of the ventricle into the subarachnoid space.

The floor of the fourth ventricle (*fossa rhomboidea*).—This is thrown into eminences and depressions indicative of the internal structures of the brain-stem subjacent to it. Its *inferior portion* is the dorsal surface of the upper portion of the

medulla oblongata; its *intermediate portion* is the dorsal surface of the pons region, while its *superior portion* belongs to the isthmus of the rhombencephalon. Its triangular lower extremity terminates as the opening of the central canal of the spinal cord. This portion is deepened at the obex and shows furrows which point downwards and converge medianwards, giving the appearance known as the **calamus scriptorius.** The mid-line of the ventricle is sharply distinguished by the well-marked **median sulcus,** which becomes shallower above than below. Throughout the length of the floor on either side of the median sulcus is a continuous ridge, the **medial eminence,** which is bounded laterally by the **limiting sulcus.** Underlying the floor of the ventricle is a layer of grey substance of varying thickness, which is continuous with that surrounding the central canal of the cord. The medial eminence is subdivided into portions of unequal width and elevation, and the limiting sulcus accordingly shows foveæ of different depths.

Fig. 591.—Dorsal Surface of the Brain-stem Showing the Anatomy of the Floor of the Fourth Ventricle. (Modified from Spalteholz.)



Beginning at the calamus scriptorius the following areas of the floor of the fourth ventricle are usually distinguished:—

The **area postrema** of Retzius is a superficial vascular structure bounded inferiorly by the tænia and overlying the terminal portion of the nucleus funiculi gracilis (clava) and a portion of the nucleus of the vagus nerve. The **funiculus separans,** a short oblique fold of the floor, composed chiefly of neuroglia, separates the area postrema from the **ala cinerea** (*trigonum vagi*), which is an oblique, grey-coloured eminence indicating the position of the middle third of the nucleus of termination (recipient nucleus) of the vagus and glosso-pharyngeal nerves. At the superior extremity of the ala cinerea is a well-marked triangular depression of the limiting sulcus known as the **inferior fovea.** Mesial to and extending above the ala cinerea is a narrow eminence lying close to the median sulcus, which represents the nucleus of origin of the twelfth nerve, the **hypoglossal eminence** (*trigonum hypoglossi*). The **nucleus intercalatus** of Van Gehuchten is a wedge-shaped portion very slightly demarcated from the hypoglossal eminence, and lying between it and the inferior fovea. This nucleus is considered by some observers as an inferior medial exten-

sion of the nucleus of termination of the vestibular nerve (area acustica), but Streeter, who has made a detailed study of the floor of the fourth ventricle by means of serial sections, doubts that it is a part of this nucleus.

Superior to the inferior fovea, and crossing each half of the floor of the fourth ventricle, are the **striæ acusticæ.** These are bundles of axones arising in the nuclei of termination of the cochlear division of the auditory nerve, which are situated in the lateral periphery of the restiform body. The bundles course around the dorsal periphery of the upper portion of the restiform body, giving it the appearance which suggested its name, then across each half of the floor of the ventricle to the median sulcus, in which they suddenly turn ventrally into the substance of the medulla oblongata, and in doing so they cross the mid-line to enter the substance of the opposite side. The striæ acusticæ vary greatly in different individuals, both in the degree of their prominence and their direction. Frequently a bundle may be discerned which courses obliquely upwards and outwards from the median sulcus to disappear in the floor further away from the mid-line and again, a bundle may depart from the transverse course before reaching the median sulcus. The striæ acusticæ cross the **area acustica.** This is the flattened elevation which occupies the whole lateral portion of the intermediate portion of the floor of the ventricle, lateral to the limiting sulcus, and extends into the inferior portion lateral to the inferior fovea. It represents the subjacent nucleus of termination of the vestibular division of the eighth cranial nerve. The dorsal and ventral nuclei of the cochlear division of the eighth nerve (*tuberculum acusticum*) are indicated by the ventro-lateral fullness in the contour of the restiform body. In many of the mammals they produce a well-marked protuberance.

In the superior portion the medial eminence occupies the greater part of the floor of the fourth ventricle, and in the upper part of the intermediate portion it presents a broader, well-marked, elongated elevation, the **colliculus facialis.** This represents the mesially placed nucleus of origin of the abducens and the genu of the root of the facial nerve, which root courses around and above the nucleus of the abducens. The nucleus of the facial is too deeply situated to produce an eminence. Lateral to this eminence is a depression of the limiting sulcus, which overlies the region of the larger portion of the nucleus of termination of the trigeminus, and is the *fovea trigemini* or **superior fovea.** The strip of the floor above the superior fovea and lateral to the medial eminence often appears greyish blue or dark brown, owing to pigmented cells subjacent to it, and is known as the **locus cæruleus.** It also represents a portion of the nucleus of the trigeminus. The most superior portion of the medial eminence becomes narrow and lies close to the mid-line. The function of the underlying grey substance producing it is uncertain, and for this reason Streeter has named the elevation **nucleus incertus,** noting that by position it is closely related to the upper portion of the nucleus of the trigeminus.

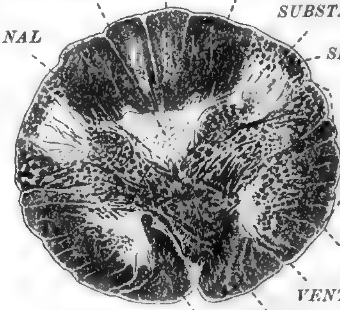
Internal structure of the medulla oblongata and pons.—The finer detail of the internal structure lies within the scope of microscopic rather than of gross anatomy. However, the significance and relations of certain of the more important and larger of the internal structures of the medulla and pons as observed in sections may be considered.

The entire brain-stem may be regarded as an upward continuation of the spinal cord, to which structures are added giving each part its peculiar character and conformation, and in which the structures characteristic of the spinal cord are modified in varying degrees.

The **pyramids,** the great descending or motor cerebro-spinal fasciculi, are directly continuous into the pyramidal fasciculi of the spinal cord. They form the extreme ventro-medial portion of the medulla, and from the fact that they contribute numerous fibres to the efferent nuclei (nuclei of origin) of the cranial nerves and to other portions of the grey substance of the brain-stem, they decrease appreciably in bulk in descending towards the spinal cord. Most of the fibres contributed to the medulla decussate as they leave the pyramids, and terminate in the grey substance of the opposite side. However, the chief **decussation of the pyramids** occurs in the lower end of the medulla. Here usually about three-fourths of the fibres then comprising the pyramids cross the mid-line to form the lateral cerebro-spinal fasciculus (crossed pyramidal tract) of the spinal cord immediately below. The remaining fourth, comprising the more lateral fibres or those furthest away from the mid-line, continues uncrossed into the spinal cord as the ventral cerebro-spinal fasciculus or direct

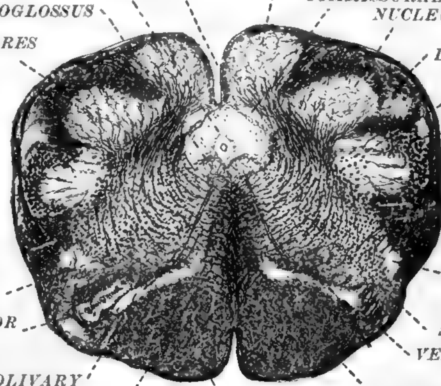
pyramidal tract. The majority of the latter fibres decussate gradually in the commissural bundle and in the ventral white commissure of the cord as they approach the levels of their termination. The proportion of fibres crossing in the chief decussation varies. Cases have been noted in which apparently the entire pyramids decussate at this level. In other cases the direct or ventral pyramidal tract may be

FIG. 592.—TRANSVERSE SECTION OF MEDULLA OBLONGATA AT THE LEVEL OF THE DECUSSATION OF THE PYRAMIDS.



much larger than usual, at the expense of the lateral. The decussation usually appears to be symmetrical and it occurs so suddenly that the fibres, in coursing from the ventral to the lateral positions, detach the tips of the ventral horns of the spinal cord from the remainder of the grey figure, and these appear as isolated, irregularly shaped masses of grey substance in transverse sections of the medulla. From this level upwards the outline of the grey figure of the cord is lost, and the cell-

FIG. 593.—TRANSVERSE SECTION OF MEDULLA OBLONGATA AT LEVEL OF THE DECUSSATION OF THE LEMNISCI.

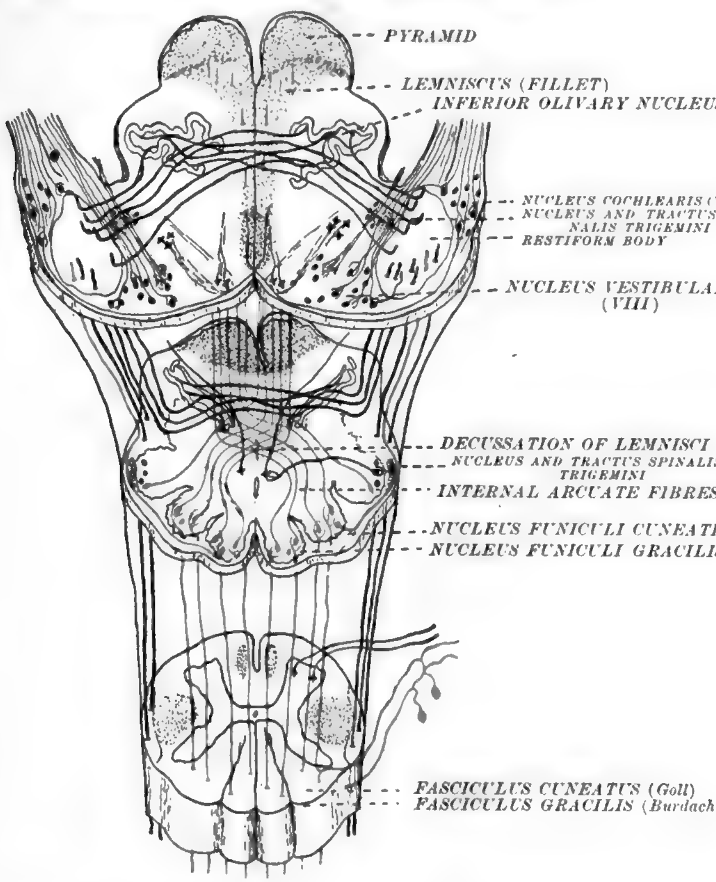


columns of the ventral horns occur in more or less detached groups as the motor nuclei of the cranial nerves.

The **origin and decussation of the lemnisci** (fillet) begins immediately above the decussation of the pyramids, and here the arrangements characteristic of the spinal cord are further modified. The dorsal portion of the grey figure of the cord is manifest up to this level, but here, after a considerable increase in its thickness,

the grey commissure gives rise to two thick dorsal outgrowths on each side of the mid-line. These dorsal projections of grey substance comprise the nuclei of termination (relays) of the chief ascending or sensory cerebro-spinal fasciculi of the spinal cord. The **nucleus funiculi gracilis** (nucleus of Goll's column) arises a little before the **nucleus funiculi cuneati** (nucleus of Burdach's column). The former extends slightly downwards from its point of origin, so that its inferior extremity is included in sections through the decussation of the pyramids (fig. 592). It produces a slight bulbous enlargement (the *clava*) of the end of the funiculus gracilis, while the nucleus funiculi cuneati corresponds to the *cuneate tubercle* of the external contour of the medulla (figs. 582 and 591). From the cells of these nuclei arise the lemniscus—the cephalad continuation of the cerebro-spinal pathway which conveys the general bodily sensations to the cerebrum. In passing out of the nuclei the fibres of the lemniscus

FIG. 594.—DIAGRAM OF THE DECUSSATION OF THE LEMNISCI.



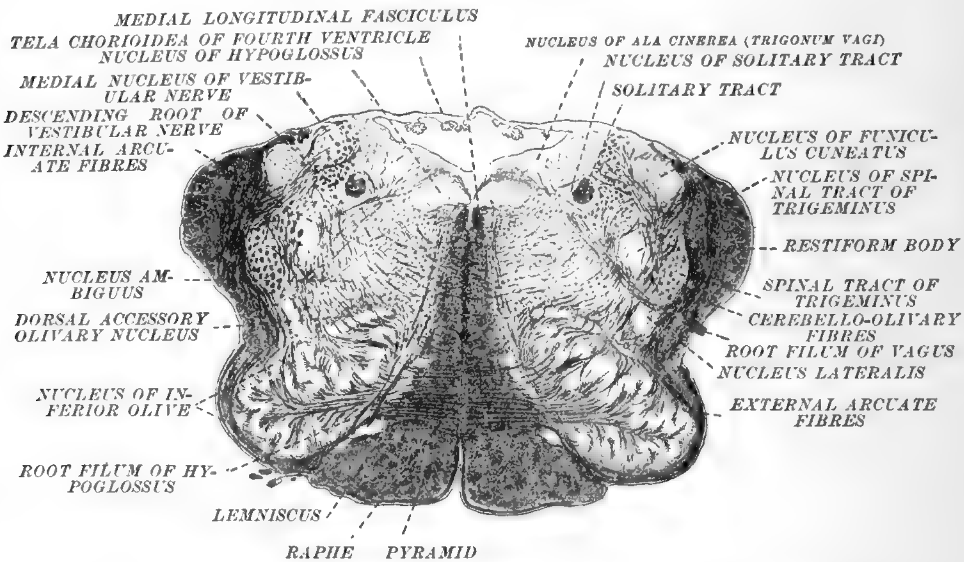
course in a ventro-medial direction. Curving around the region of the central canal, they contribute largely to the **internal arcuate fibres,** then, sweeping across the mid-line, they convert it into the **raphe,** and immediately after crossing (decussating) they turn cephalad and collect to form the bundle known as the **lemniscus.**

In the medulla, the lemnisci are two thin bands of fibres spread vertically on each side of the raphe, with their lower or ventral edges thicker than their dorsal edges. In their course towards the cerebrum they increase in bulk, owing chiefly to fibres being added to them from the nuclei of termination of the afferent roots of the cranial nerves. In passing through the region of the pons, the lemnisci gradually become spread horizontally, and beyond the pons their then more outer portions are further displaced and come to course in the lateral borders of the isthmus rhombencephali and mesencephalon, while the inner portions remain nearer the mid-line. This lateral spreading of each lemniscus produces the **lateral lemniscus** and the **medial**

lemniscus, distinguished in transverse sections of the superior pons and mesencephalic regions of the brain-stem (fig. 609).

The **reticular formation** of the medulla and pons region is considerably more abundant than in the spinal cord. As in the spinal cord, it consists of grey substance through which nerve-fibres, singly and in small bundles, course in all directions, and more sparsely than in other regions. In the medulla it is traversed by the internal arcuate fibres. It may be considered an enlarged continuation of the middle portion of the grey column of the cord, traversed by numerous fibres, giving it the reticulated appearance which suggests its name. Its numerous nerve-cells belong, for the most part, to the association and commissural systems of the brain-stem, and, therefore, the fibres arising in it correspond to the fasciculi proprii of the spinal cord. As in the cord, most of the fibres are of short course, serving to associate different portions of the same level and adjacent levels with each other. Those of long course show a tendency to collect into a small, well-marked bundle which courses one on each side close to the mid-line, ventral to the central canal in the closed part of the medulla, and near the floor of the fourth ventricle, in the open part. In the mesencephalon this bundle is again situated ventral to the aquæductus cerebri.

Fig. 595.—Transverse Section of Medulla Oblongata Through Nuclei of Vagus and Hypoglossus and Through the Middle of the Olives.



This bundle is known as the **medial longitudinal fasciculus** (posterior longitudinal bundle). It corresponds more nearly to the ventral fasciculus proprius of the spinal cord than to others of the fasciculi proprii. In the medulla it appears as the dorsal edge of the lemniscus, but in the shifting of the position of the lemniscus in the pons region, it becomes isolated. By position it is especially adapted for the association of the nuclei of the cranial nerves. Evidence has been found that those fibres which arise in the corpora quadrigemina and descend the spinal cord in its sulco-marginal fasciculus, pass through the medulla in the medial longitudinal fasciculus.

The **inferior olivary nucleus** is an added structure in the medulla oblongata, i. e., it has no homologue in the spinal cord. The two of them occupy the olivary prominences, *the olives* of the exterior, and constitute the most conspicuous and striking isolated masses of grey substance in sections of the medulla. They appear as crenated laminæ of grey substance folded so as to encup a dense mass of white substance, and in actual shape the entire nucleus has the form of an irregular corrugated cup with the opening or **hilus** on the side towards the mid-line. The mass is so crumpled that the diameter of the hilus is appreciably less than the length of the nucleus, and thus transverse sections of either extremity of it appear as closed capsules.

There are several small detached portions of the olivary nucleus known as the **accessory olivary nuclei.** These are named according to their position with reference to the chief portion or olive proper. They are less corrugated than the chief nucleus, and appear rod-like in sections. The largest is the *dorsal accessory olivary nucleus.* The *medial accessory olivary nucleus* is widest at its inferior end, which extends a little below the inferior extremity of the chief nucleus. The *lateral accessory olivary nucleus* is the smallest. In serial sections the accessory nuclei are found to be plates of grey substance and usually continuous with one another.

The olivary nuclei are mainly cerebellar connections. By both ascending and descending fibres each cerebellar hemisphere is connected with the olivary nucleus of the same and opposite sides. These fibres necessarily pass between the cerebellum and the olives by way of the restiform body, and, in so doing, form an obliquely coursing bundle in the lateral border of the medulla known as the **cerebello-olivary fibres** (fig. 595).

The **arcuate fibres** are referred to as internal and external, according as they course dorsal or ventral to the inferior olivary nucleus.

The **internal arcuate fibres** comprise fibres destined for both the cerebellum and cerebrum, and also for the association of the tegmental grey substance of the two sides in which they course. Certain of the fibres passing between one restiform body (cerebellar hemisphere) and the olive of the opposite side course internal to the olive of the same side, and thus form the ventral portion of the internal arcuate fibres.

Fig. 596.—Reconstruction of the Inferior Olivary Nucleus, Dorso-lateral Surface. (After Sabin.)

As noted above, the internal arcuate fibres consist in greatest part of cerebro-afferent fibres, arising from the cells of the nucleus funiculi gracilis and funiculi cuneati and sweeping downwards and decussating to form the lemniscus of the opposite side. However, all the fibres arising in these nuclei do not enter the lemniscus. A few of them cross the mid-line with the internal arcuates, but pass on to enter the restiform body (cerebellar hemisphere) of the opposite side. Some of these course ventrally and, upon approaching the olive of the opposite side, are deflected around the ventral side of both the olive and the pyramid, and thus pass to the restiform body as external arcuate fibres also. Certain of the internal arcuate fibres arise from the cells of the nuclei of termination of the cranial nerves and from small cells situated in the grey substance of the reticular formation. These, in crossing the mid-line, correspond to the white commissures of the spinal cord. Some of them terminate in the medulla; others join the lemniscus and pass towards the cerebrum; others reach the cerebellar hemisphere of the opposite side.

The **external arcuate fibres,** in addition to those mentioned above, comprise certain fibres which arise in the nuclei funiculi gracilis and cuneati and pursue a dorsolateral course to enter the restiform body of the same side. These form the dorsal segment of the external arcuates. The greater mass of the external arcuates are cerebello-olivary fibres. Certain of those passing from one olive to the restiform body of the opposite side are deflected at the raphe, and course on the ventral side of both the other olive and the pyramid in order to reach the cerebello-olivary bundle. Like-

wise, those passing from the restiform body to the opposite olive are deflected by the olive of the same side and pursue a similar course to the raphe. While out of the hilus of each olive streams a dense mass of white substance, yet many of the fibres concerned with the olive pierce its walls from all sides.

Many of the external arcuate fibres are said to be interrupted in the **nucleus arcuatus.** This is a thin sheet of grey substance, variable in amount, which lies on the ventral aspect of each pyramid, and, though it decreases inferiorly, it may be evident down to the decussation of the pyramids. The nucleus receives its name from the fact that its larger portion is interpolated in the course of the external arcuates.

FIGS. 597 AND 598.—DIAGRAMS SHOWING THE COMPOSITION OF THE CEREBELLAR PORTIONS OF THE INTERNAL AND EXTERNAL ARCUATE FIBRES.

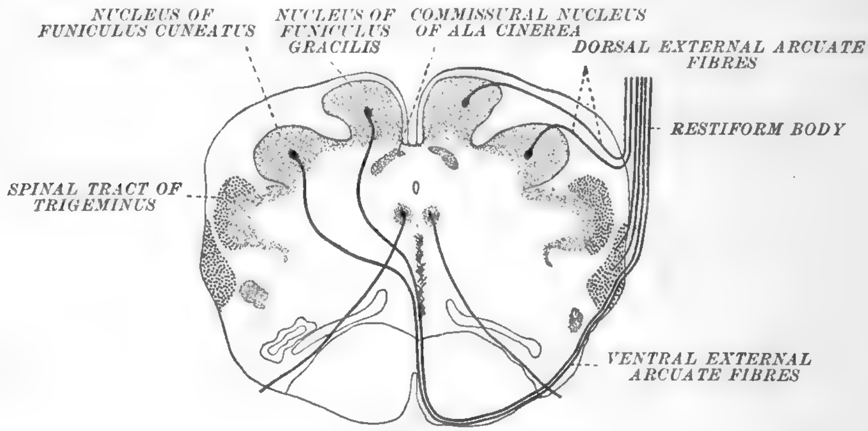


Fig. 597.

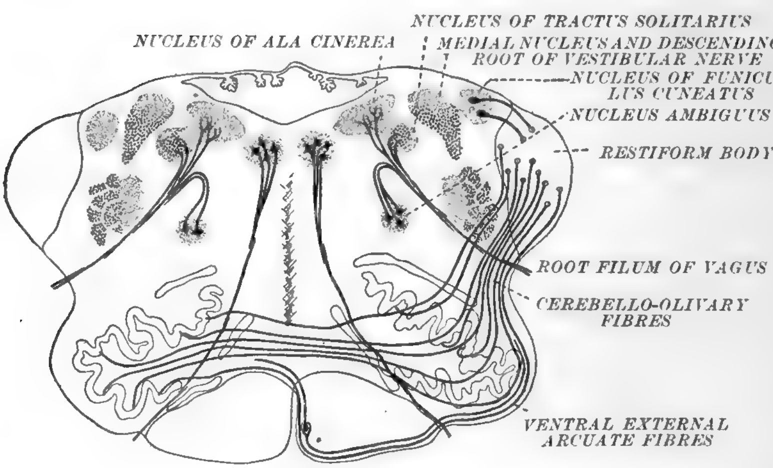


Fig. 598.

The arcuate fibres of longer course, like the olives with which they are largely concerned, have no homologues in the spinal cord.

The *central canal* of the closed portion of the medulla is surrounded by a greater amount of grey substance, **substantia grisea centralis,** than is the canal in the spinal cord. This is largely gelatinous substance, *the central gelatinous substance*, and the nerve-fibres in coursing through the grey substance are partially deflected by it, leaving it as a cylindrical, more evident area of grey substance than in other regions. In the open portion of the medulla the substantia grisea centralis naturally forms a more transparent lamina just under the floor of the fourth ventricle. In the mesencephalon it again surrounds the reformed canal or aquæductus cerebri.

The **central connections of the cranial nerves** are most easily homologised with spinal-cord structures. Functionally the cranial nerves are of three varieties:—(1) the motor or efferent nerves, comprising the oculomotor, the trochlear, the abducens, the spinal accessory, and the hypoglossus; (2) the sensory or afferent, comprising the olfactory, the optic, and the acoustic; and (3) the mixed, motor and sensory nerves, comprising the trigeminus, the facial, the glosso-pharyngeal, and the vagus. The **nuclei of origin** of the motor or efferent cranial nerves and the efferent portions of the mixed nerves are directly continuous with the cell columns of the ventral horns of the spinal cord, while the emerging root filaments and roots of these nerves correspond to the ventral roots of the spinal nerves. The **nuclei of termination** of the afferent or sensory cranial nerves and of the sensory portions of the mixed nerves correspond directly to the nuclei of the funiculus gracilis and funiculus cuneatus, and, functionally, are merely anterior continuations of these nuclei.

The nuclei of the efferent or motor cranial nerves lie in two parallel lines, one near the mid-line and the other more laterally placed. The nuclei giving origin to the oculomotor, the trochlear, the abducens, and the hypoglossus are near the mid-line, and correspond to the ventro-medial and dorso-medial cell groups of the ventral horns of the spinal cord; the nuclei of origin of the motor portion (portio minor) of the trigeminus, of the facial, and the nucleus ambiguus giving origin to the motor portions of the glosso-pharyngeal and vagus nerves, together with the nucleus of the spinal accessory, correspond to the ventro-lateral and dorso-lateral cell-groups of the ventral horns of the spinal cord. The nerve-roots having medial nuclei of origin are those which make their exit from the brain-stem along the more medial superficial line, while those having the more lateral nuclei comprise the more lateral line of roots apparent on the surface of the stem. The first two pairs of cranial nerves, the olfactory and optic, are attached to the prosencephalon. These are purely sensory, and make their entrance near the mid-line of the brain, both having superficially placed nuclei of termination. Of the other nerves, all having sensory or afferent functions enter the brain along the lateral or more nearly dorsal line, and the ganglia giving origin to their afferent axones correspond directly to the ganglia of the dorsal or afferent roots of the spinal nerves.

Commissural and associational neurones are much more numerous in the brain-stem than in the spinal cord. Their axones serve to connect the structures on the two sides of the mid-line and to associate the different levels of the same side. Just as in the spinal cord, those of longer course correspond to the fasciculi proprii.

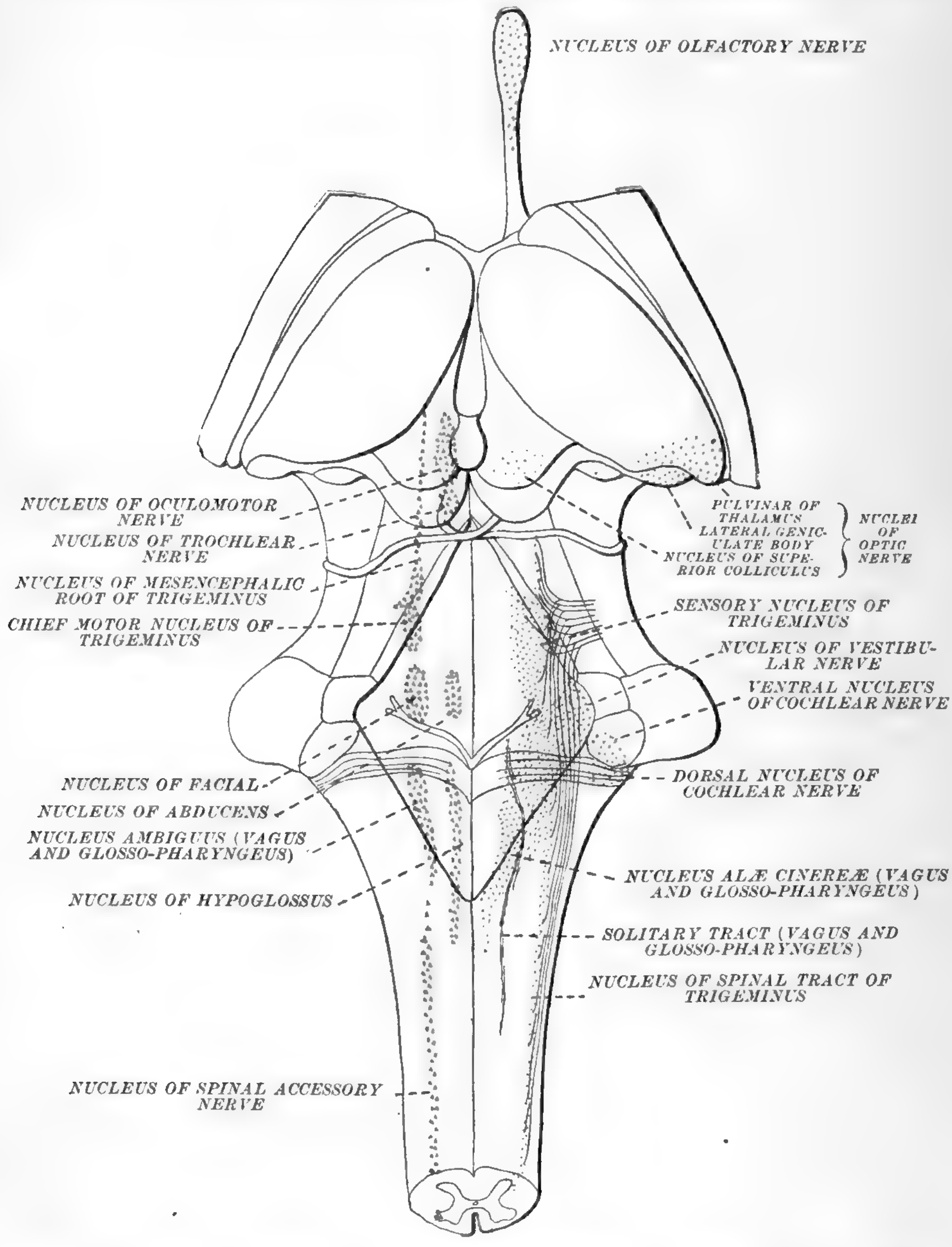
Of the twelve pairs of cranial nerves, eight pairs are attached to the medulla oblongata and pons, viz., the trigeminus, abducens, facial, acoustic, glosso-pharyngeal, vagus, spinal accessory, and hypoglossus.

The **hypoglossus,** the motor nerve of the tongue, has its nucleus of origin beginning in the lower portion of the floor of the fourth ventricle at the level of the striæ acusticæ. It is a long nucleus, lying close to the mid-line and just under the floor of the ventricle (hypoglossal eminence) and extending down to the region of the funiculus separans. Here it curves ventrally to a slight degree, and below the obex assumes a position ventro-lateral to the central canal, and thus extends a short distance below the level of the inferior tip of the olive. The nerve arises as a series of rootlets which traverse the entire thickness of the medulla (fig. 595), to emerge in line in the furrow between the olive and the pyramid and fuse to form the trunk of the nerve. The lowermost of the rootlets usually emerge below the olive. The nucleus receives impulses—(1) from the cerebrum by way of divergent fibres from the pyramid of the opposite side (voluntary); (2) impulses brought in by the sensory fibres of the cranial nerves (reflex); and (3) by axones from other levels of the medulla (associational). None of its axones are supposed to decussate, though numerous commissural fibres are known to pass between the nuclei of the two sides.

The **spinal accessory** is likewise a purely motor nerve, and has a laterally placed, long, and much attenuated nucleus of origin. Above, its nucleus is in line with and practically continuous with the nucleus giving motor fibres to the vagus and glosso-pharyngeus (nucleus ambiguus). Below, it consists of the dorso-lateral group of cells of the ventral horn of the first five or six segments of the spinal cord. The nerve arises as a series of rootlets which emerge laterally and join a common trunk, which passes upwards parallel with the medulla to turn outwards in company with the vagus. (See fig. 580.) The upper rootlets arise from that part of the nucleus contiguous to the nucleus ambiguus, and are described as comprising the medullary

or *accessory part* of the nerve; those which arise from the ventral horn cells below are described as the *spinal part*. The trunk of the spinal accessory fuses with the vagus in the region of its two ganglia, and, before separation, contributes fibres (the accessory part) to the trunk of the vagus. The accessory fibres are distributed as motor fibres to the muscles of the larynx; the spinal part is distributed to the sterno-

FIG. 599.—SCHEME SHOWING THE RELATIVE SIZE AND POSITION OF THE NUCLEI OF ORIGIN (RED) OF THE MOTOR AND THE NUCLEI OF TERMINATION (BLUE) OF THE SENSORY CRANIAL NERVES.



mastoid and trapezius muscles. The nucleus of the spinal accessory receives terminal twigs of pyramidal fibres and is otherwise subjected to influences similar to those affecting the cells giving origin to the motor roots of the spinal nerves.

The **vagus** or pneumogastric and the **glosso-pharyngeus,** though they have widely different peripheral distributions, are so similar in origin and central connec-

tions that they may be described together. Both contain efferent fibres, though both are in greater part sensory. They are very similar as to the origin of both their efferent and afferent components. The afferent fibres of the vagus arise in its ganglion jugulare and its ganglion nodosum (ganglion of the trunk); the afferent fibres of the glosso-pharyngeus arise in its ganglion superius and its ganglion petrosum. In both nerves these fibres enter the lateral aspect of the medulla and bifurcate into ascending and descending branches, similar to those of the dorsal root-fibres in the spinal cord. Some of these branches terminate in practically the same level of the medulla about cell-bodies situated on the same and the opposite sides. Such end chiefly in the nuclei of the hypoglossal and spinal accessory, and about the cells giving origin to the efferent components of the vagus and glosso-pharyngeus themselves—short reflex fibres. However, most of the afferent fibres terminate in the nucleus of termination of the vagus and glosso-pharyngeus:—(1) the **nucleus of the ala cinerea,** the middle portion of which is indicated in the floor of the fourth ventricle by the ala cinerea; (2) in the closed portion of the medulla, the lower end of the nucleus of the ala cinerea comes to lie in the dorso-lateral proximity of the central canal, and this portion is known as the *commissural nucleus of the ala cinerea* (figs. 593 and 597) from the fact that fibres may be seen which pass directly from it across the mid-line; (3) most of the descending branches of the bifurcated fibres collect to form the **solitary tract,** a compact bundle situated dorsally just lateral to the nucleus of the ala cinerea and quite conspicuous in sections of the medulla. The fibres of this bundle terminate in the *nucleus of the solitary tract,* which is but a ventro-lateral and downward continuation of the nucleus of the ala cinerea enclosing the bundles forming the tract. It is probable that the fibres of the solitary tract are chiefly from the vagus (pneumogastric), though Bruce has found evidence that the glosso-pharyngeal contributes to it appreciably. It decreases rapidly in descending the medulla, owing to the rapid termination of its fibres about the cells of its nucleus, but it is believed to extend as far downwards as the level of the fourth cervical segment of the spinal cord. This being in the level or origin of the phrenic nerve, the funiculus may be in part a link in the respiratory apparatus which aids in the co-ordinated respiratory movements. The axones given off by the cells of the terminal nuclei of the vagus and glosso-pharyngeus course on both sides of the mid-line, the greater portion perhaps decussating to be distributed to the structures of the opposite side. Some join the lemniscus of the opposite side and pass into the cerebrum; others are distributed to the motor neurones of the medulla and cervical cord of the same and opposite sides (reflex axones), and no doubt others form central connections with the cells of the reticular formation of the medulla, though their precise relations have not been determined.

The nuclei of origin of the motor fibres of the vagus and glosso-pharyngeus are the **dorsal efferent nucleus** and the **nucleus ambiguus.** The cells of the dorsal nucleus lie somewhat clustered in the ventro-mesial side of the nucleus of the ala cinerea and lateral to the nucleus of the hypoglossus. Their axones pass outwards among the entering or afferent vago-glossopharyngeal fibres. The *nucleus ambiguus* or ventral efferent nucleus lies in the lateral half of the reticular formation, about mid-way between the olive and the line traversed by the rootlets of the two nerves. Its upper end is larger. Its cells are considerably dispersed by the fibres of the reticular formation. The axones arising from its cells course at first dorsalwards and then turn abruptly outwards to join the rootlets of the vagus or glosso-pharyngeus, as the case may be. The vagus is thought to receive more efferent fibres from the two motor nuclei than does the glosso-pharyngeus, and Cunningham notes that it may be questioned whether the latter contains any motor fibres at all, there being paths by which the fibres of its motor branch (to the stylo-pharyngeus muscle) might enter it other than direct from the motor nuclei.

The **acoustic nerve** is a double nerve, both divisions of which are purely sensory. It enters the brain at the lateral aspect of the junction of the medulla oblongata and pons. It is best described as two nerves:—

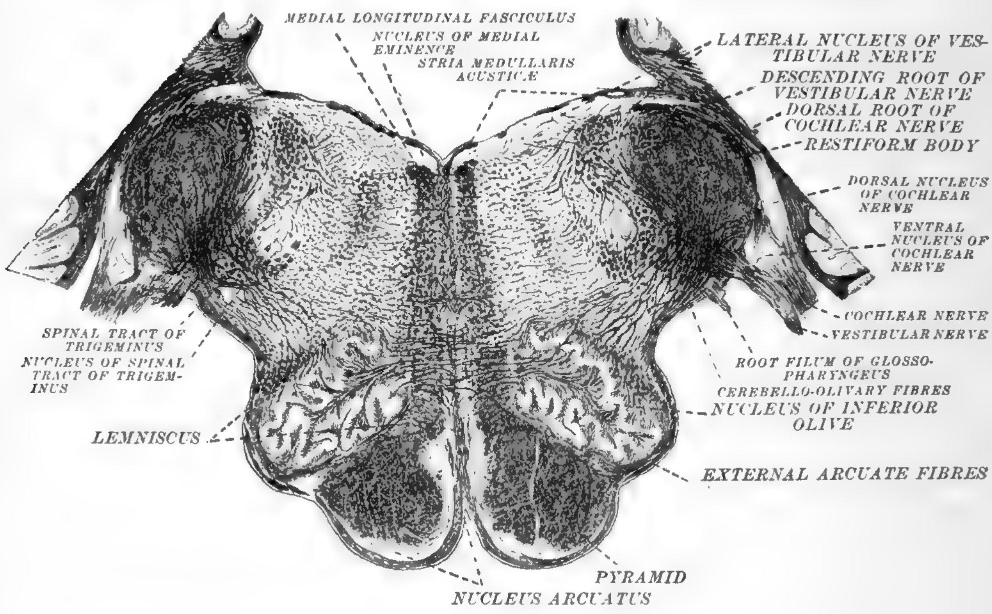
(1) The **vestibular nerve** arises as the central processes of the bipolar cells of the *vestibular ganglion,* and passes into the brain-stem on the inner side of the restiform body to find its nucleus of termination (nucleus vestibularis) in the floor of the fourth ventricle. This nucleus occupies a triangular area of considerable extent (area acustica, figs. 591 and 594), and is usually subdivided into a *lateral nucleus* (Deiters'), a *medial nucleus* (Schwalbe's), a *superior nucleus* (Bechterew's), and an

inferior nucleus (nucleus spinalis). The latter is a downward prolongation of the general nucleus vestibularis which accompanies the *descending root* of the nerve.

From the cells of the lateral and inferior nuclei axones are given off which form reflex paths to the lateral column of the spinal cord (vestibulo-spinal fasciculus, fig. 571). From both the lateral nucleus and the superior nucleus a special path is given off which passes upwards and terminates in the nucleus fastigii (cerebelli) of the opposite side and in the nucleus dentatus and the cortex of the vermis. Also, fibres arising in the nuclei fastigii are said to terminate in the lateral (Deiters') nucleus in addition to those which descend into the ventral marginal fasciculus of the spinal cord. From the medial and also from the superior nucleus fibres pass to the medial longitudinal fasciculus of both sides, and are distributed to the nucleus of the abducens of the same side and to the nuclei of the trochlear and oculomotor nerves and of the motor portion of the trigeminus of the same and opposite sides. Other fibres arising in the vestibular nucleus ascend to the lateral portion of the thalamus.

Many of the anatomical details of the central connections of the vestibular nerve have not yet been determined with exactness. In addition to whatever other functions it may have, it is considered to be the nerve of equilibration, and the connec-

Fig. 600.—Transverse Section of Medulla at Inferior Border of Pons.



tions noted above may be considered the pathways by which it exercises this function. The fibres of the apparatus which are represented in the spinal cord are supposed to convey impulses to the ventral horn (motor) cells of the cord as far down as the lumbar region.

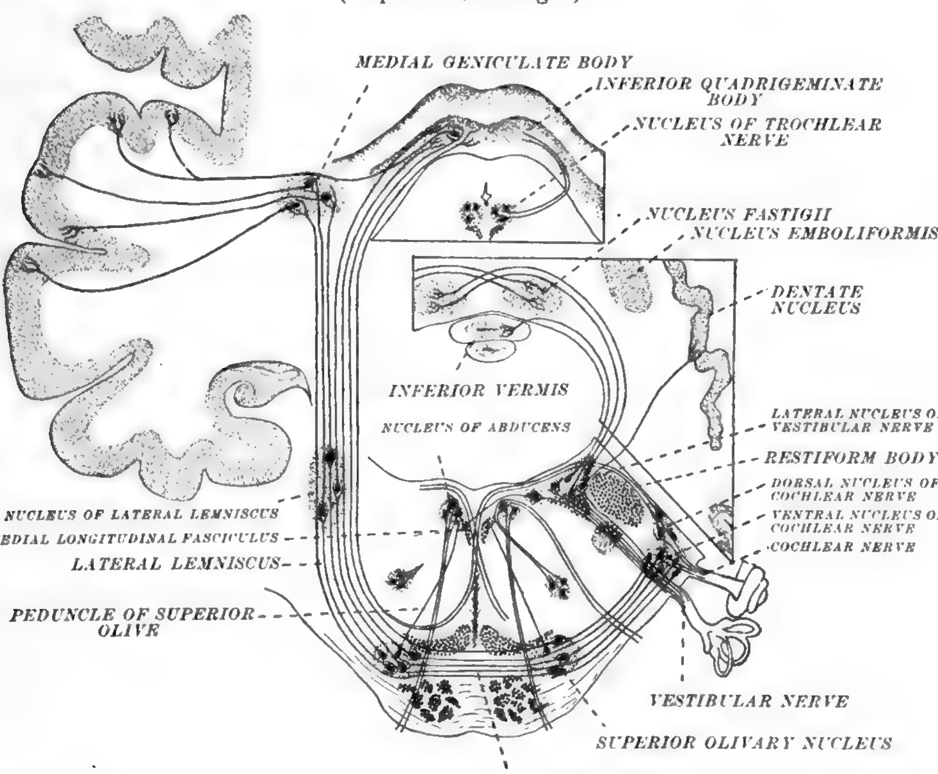
(2) The **cochlear nerve,** probably the auditory nerve proper, arises as the central processes of the bipolar cells of the *spiral ganglion* of the cochlea. In the lateral periphery of the restiform body, just as it enters the pons, the nerve finds its two nuclei of termination, the *ventral nucleus* and the *dorsal nucleus* (tuberculum acusticum, fig. 591).

From the dorsal nucleus arise the *striæ medullares acustici.* These bundles, more or less inconstant in man, pass around the dorsal aspect of the restiform body and course just under the ependyma of the floor of the fourth ventricle to the mid-line, where they suddenly turn downwards into the substance of the medulla, and in doing so, cross to the opposite side and join the lemniscus. As the lemniscus becomes separated higher up into a medial and lateral portion, these fibres course in the lateral lemniscus and are distributed chiefly to the grey substance of the inferior quadrigeminate body of that side.

From the ventral nucleus of termination fibres arise which terminate about the

cells of the **superior olivary nucleus** of the same and opposite sides. The superior olive is a small accumulation of grey substance which lies in the level of the posterior portion of the pons, and in line with the much larger inferior olivary nucleus of the medulla. However, it is not analogous to the latter in any sense. The two superior olives form links in the central acoustic chain. From cells of the superior olivary nucleus of the same and opposite sides, fibres arise which pass by way of the lateral lemniscus and terminate in the grey substance of the inferior quadrigeminate body and in the medial geniculate body, thus connecting these bodies with the ventral nucleus of the cochlear nerve of the opposite side. From the medial geniculate body fibres arise which pass to the cortex of the superior gyrus of the temporal lobe. This path is supplemented by fibres arising in the inferior quadrigeminate body, which likewise go to the temporal lobe. In the lateral lemniscus some of the acoustic fibres are interrupted by cells of the *nucleus of the lateral lemniscus.* In crossing the mid-line the fibres from the two sources form a more or less compact bundle, the **corpus**

Fig. 601.—Scheme showing Some of the Central Connections of the Acoustic Nerve. (In part after Edinger.)



trapezoideum. To this are added fibres crossing between the **nuclei trapezoidei,** smaller masses of grey substance just ventral to the superior olives.

Also, some fibres arising in the nuclei of termination of the cochlear nerve pass to the inferior quadrigeminate body of the same side. On the other hand, the connection with the medial geniculate body is thought to be wholly a crossed one. Further, a few fibres are described as terminating in the *superior quadrigeminate body* of both the same and the opposite side.

All the fibres arising in the superior olivary nucleus do not enter the corpus trapezoideum and the lateral lemniscus. A small bundle, the **peduncle of the superior olive,** arises in each nucleus and courses dorsally to the region of the nucleus of the abducens. Here certain of its fibres terminate about the cells of the nucleus of the abducens, while others enter the medial longitudinal fasciculus and pass to the nuclei of the trochlear and oculomotor nerves, thus establishing connections between auditory impulses and eye movements.

The **facial nerve** is also composed of two parts. Its larger part is purely efferent or motor, while its considerably smaller root or **pars intermedia** contains for the most part sensory fibres. Both the facial nerve and the abducens have their nuclei within the level of the pons, though the roots of both appear from under its inferior border.

The *nucleus of origin* of the motor portion of the facial lies in the ventro-lateral region of the reticular formation, in line with the nucleus ambiguus. The axones given off by the cells of this nucleus collect into a bundle which, instead of passing ventrally and directly to the exterior, courses at first dorso-mesially up to the mesial side of the nucleus of origin of the abducens (ascending root of the facial); then it turns and courses anteriorly for a few millimetres, parallel with the nucleus of the abducens and immediately beneath the floor of the fourth ventricle (genu facialis); then it again turns abruptly and pursues a ventro-lateral direction to its point of exit at the inferior border of the pons, near the entrance of the vestibular nerve. Its exit usually involves a few of the pons fibres. In transverse sections through the middle of the nucleus of the abducens the genu of the facial appears as a compact, transversely cut bundle at the dorso-medial side of this nucleus.

The **pars intermedia** (nervus intermedius) of the facial is chiefly afferent or sensory. It is said to contain efferent secretory (salivary) fibres which arise from cells scattered in the reticular formation about the dorsal periphery of the facial nucleus. Though in company with the large motor portion during the exit of the latter, yet, quite close to the point of attachment, the pars intermedia may frequently be distinguished as a separate root. Shortly, however, it becomes intimately united with the main trunk. Its afferent fibres arise from the cells of the *geniculate ganglion* of the facial, and from numerous cells scattered within the trunk of the nerve. These cells correspond to those of the spinal ganglia, each giving off a single process which bifurcates into a peripheral and a central branch. The central branch finds its nucleus of termination in what may be called the mixed lateral sensory area of the brain-stem—the region bounded by the nucleus of termination of the vestibular nerve, the superior extremity of the nucleus of the solitary tract, and the nucleus of termination of the trigeminus.

The nucleus of origin of the (motor) facial nerve receives impulses from the lower portion of the anterior central gyrus of the cerebral cortex by way of the pyramid, which gives off fibres both to the nucleus of the same side and by way of arcuate fibres through the raphe to the nucleus of the opposite side. It also receives fibres from the root of the trigeminus, the great sensory nerve of the face, and from the central connections of the auditory nerve.

The **abducens** is a small, purely motor nerve, which supplies the external rectus muscle of the eye. Its *nucleus of origin* lies close to the mid-line in the medial eminence of the floor of the fourth ventricle, and in line with that of the hypoglossus. Its root-fibres pursue a ventral course, inclining a little outwards and curving inferiorly to emerge from under the inferior border of the pons. They pass lateral to the pyramid, and often between some of its fasciculi. The nucleus receives cortical or voluntary impulses by way of the pyramid, chiefly of the opposite side. Its connection with the auditory apparatus and the medial longitudinal fasciculus has already been noted. It probably receives afferent impulses through the fibres of the trigeminus.

The **trigeminus** is considerably larger than any of the nerves inferior to it, and has the most extensive central connections of any of the cranial nerves. It is a mixed nerve, but, unlike the facial, its *sensory root* is the larger (portio major) and its small *motor root* (portio minor) is separate from the main trunk soon after its emergence. The two roots pass together through the brachium pontis in line with the facial nerve, and find their nuclei in the grey substance underlying the floor of the fourth ventricle.

The large **sensory portion** serves as the nerve of general sensibility for the face from the vertex of the scalp downwards, and thus it corresponds to the afferent fibres not only for its own motor root, but of all the nerves giving motor supply to structures underlying its domain. Its fibres arise from its large, trilobed, *semilunar* (Gasserian) *ganglion*, situated outside the brain. This corresponds to the dorsal root ganglion of a spinal nerve, and its cells give off the characteristic T-fibres with peripheral and central branches. The central or afferent branches upon entering the brain-stem bifurcate into ascending and descending divisions, just as the entering dorsal

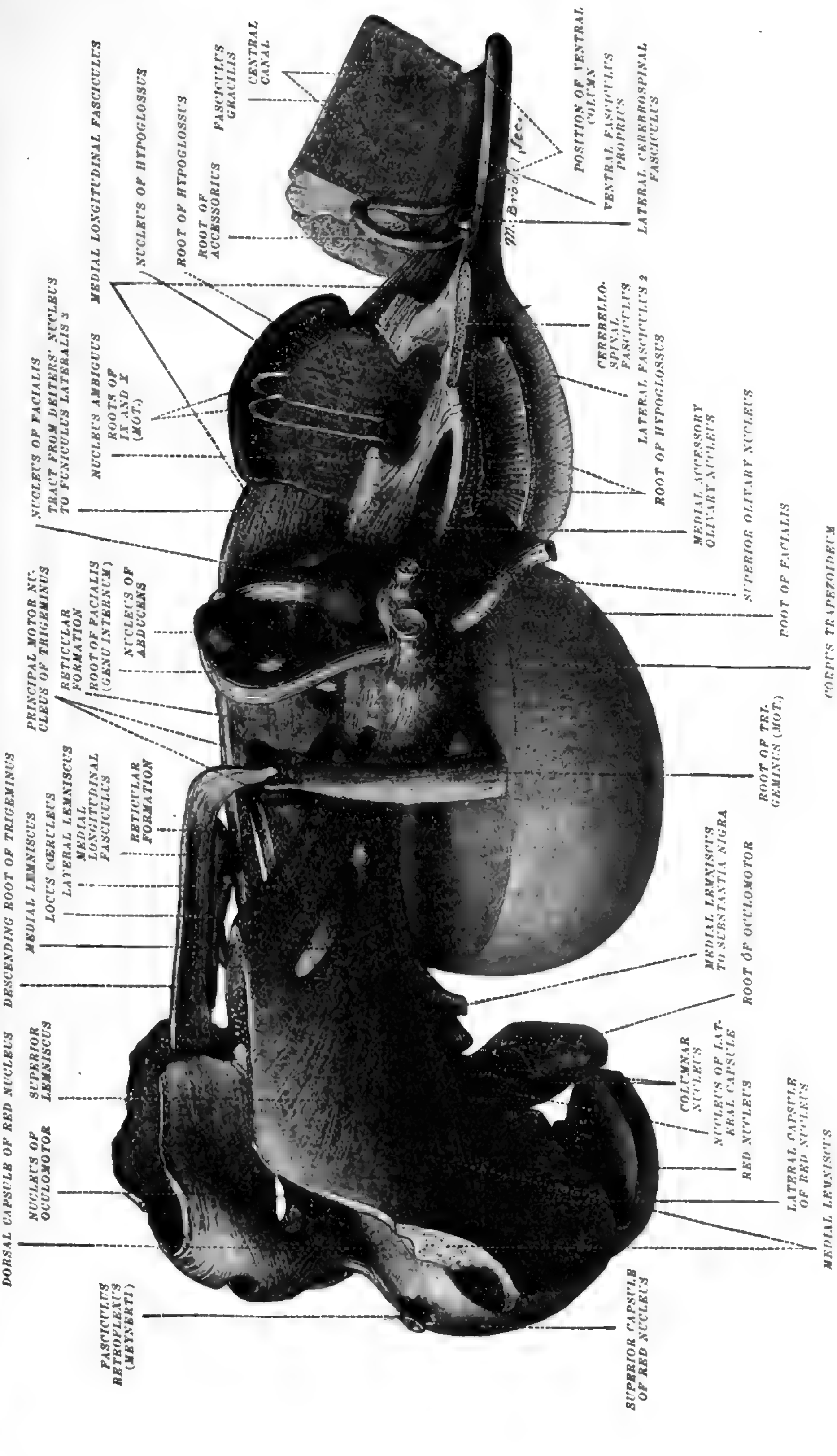


FIG. 602.—Drawing of Model of Brain-stem showing the Nuclei of Origin of the Motor Cranial Nerves. (After Sabin.)

root-fibres of the spinal nerves, and find their *nucleus of termination* in a dorso-lateral column of grey substance, which consists of the upward continuation of the gelatinous substance of Rolando of the spinal cord. Opposite the entrance of the nerve is a considerably thickened portion of this column of grey substance, known as the *sensory nucleus* of the trigeminus, and the remainder below is called the *nucleus of the spinal tract* (fig. 599). After bifurcation the branches of the entering fibres of the trigeminus terminate about the cells of these nuclei. The descending branches are much longer than the ascending, and in passing downwards form the **spinal tract of the trigeminus,** well marked in all transverse sections of the medulla oblongata (figs. 592, 593, 595, 600). The spinal tract decreases rapidly in descending the medulla, owing to the rapid termination of its fibres in the nucleus of the tract. It has been traced as far down as the second cervical segment of the spinal cord. The ascending branches being short, most of them terminate in the 'sensory nucleus,' and, therefore, the upward extension of the nucleus of termination of the fifth nerve is both very short and scant.

The *nucleus of origin* of the **motor root** of the trigeminus is also in two parts. The *principal nucleus* lies on the dorso-medial side of the 'sensory nucleus,' a nucleus of termination. It gives rise to the greater part of the motor root, and its fibres are distributed to the muscles of mastication. Above the principal nucleus and along the line of the locus cœruleus extends the *nucleus of the mesencephalic* (descending) *root.* The cells of this latter nucleus are thinly scattered as high up as the posterior commissure of the cerebrum, and the mesencephalic root arising from them gradually increases (accumulates) as it passes through the mesencephalon to the superior level of the pons, where it joins the fibres arising in the principal nucleus.

The distribution of the fibres of the mesencephalic root is not clearly settled. Collaterals from some of them are known to terminate about the cells of the principal nucleus, and thus an impulse carried by them is not only given a wider distribution, but is perhaps reinforced by the interpolation of another neurone. It is thought that all of its fibres are not supplied to the muscles of mastication proper: some may supply the tensor veli palatini and tensor tympani. (Kölliker.) Both nuclei receive cortical fibres from the pyramids.

Axones from the nucleus of termination of the afferent portion of the trigeminus are distributed—(1) to the nuclei of its motor portion of the same and opposite sides (short or simple reflex fibres); (2) to the nuclei of the motor cranial nerves; (3) to the thalamus of the same and chiefly the opposite side, and thus, through interpolation of thalamic cells, their impulses reach the somæsthetic area of the cerebral cortex. These fibres ascend in the reticular formation instead of coursing strictly within the lemniscus. Fibres crossing the mid-line contribute to the internal arcuates.

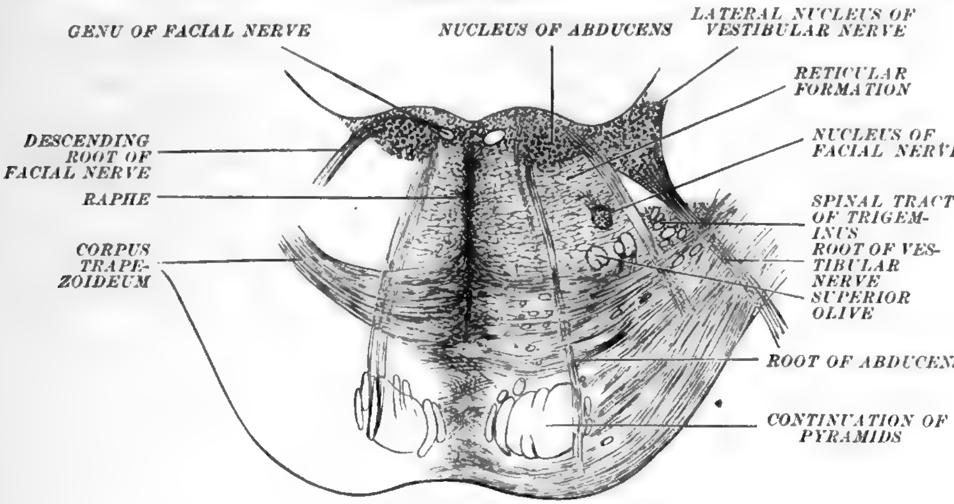
The internal structure of the pons.—The nuclei and roots of the trigeminus, abducens, facialis, and acusticus are contained within the level of the pons, and their position and course have been described above. The pons proper (the bridge) consists of a mass of transversely running fibres continuous on either side into the brachia pontis or middle cerebellar peduncles. In the animal series the relative amount of these fibres varies with the size of the cerebellum, with which they are connected. They are relatively more abundant in man than in other animals.

In transverse sections the pons fibres are seen to course ventrally about the main axis of the brain-stem, making it possible to divide the section into a *basilar* or *ventral part* and a *dorsal part* (*tegmentum*). The fibres in their transverse and ventral course around the medulla oblongata involve the pyramids. At the inferior border of the pons the fibres little more than separate the pyramids as such from the main axis of the brain-stem, but more anteriorly the pons fibres pass through the pyramids, splitting them into the **pyramidal fasciculi.** These pyramidal or chief *longitudinal fibres* of the pons are the continuation of the basal portion of the cerebral peduncles through the pons, to emerge as the pyramids proper at its inferior border. They occupy an intermediate or central area among the pons fibres, leaving the periphery of the pons uninvaded. The *superficial pons fibres* form the solid bundle of its ventral and lateral periphery and the *deep pons fibres* form a similar bundle dorsally enclosing the area of pyramidal fasciculi.

In transverse sections through the *inferior portion* of the pons, the *dorsal or tegmental part* consists of structures continuous with and analogous to the structures of

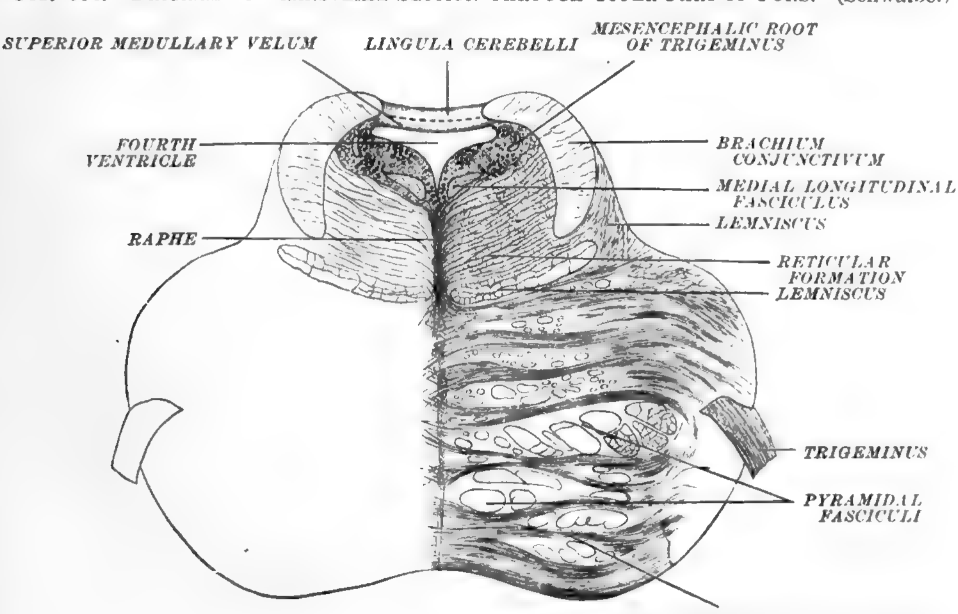
the medulla oblongata immediately below, exclusive of the pyramids. In addition, this region contains the superior olivary nucleus and the corpus trapezoideum. The significance of these structures and their relation to the nucleus of termination of the

Fig. 603.—Diagram of Transverse Section of Inferior Part of Pons. (Schwalbe.) The restiform body, not included, occupies the curved space lateral to the nucleus of vestibular nerve.



cochlear nerve is shown in fig. 601. In this region the *lemniscus* (fillet) changes from the vertical to the horizontal arrangement, and its lateral edges are becoming drawn outwards to form the lateral lemniscus of the regions superior to this. The medial

Fig. 604.—Diagram of Transverse Section Through Upper Part of Pons. (Schwalbe.)



longitudinal fasciculus, left alone by the change in the arrangement of the lemniscus, maintains its dorsal position throughout the pons and into the mesencephalon above.

The **restiform body** acquires in this inferior region a more dorso-lateral position than in the medulla below. Its fibres are beginning to turn upwards in their course

to the cerebellum mesial to the brachium pontis. Here the restiform body is nearing completion, and the fibres now contained in it may be summarised as follows:—

(1) The fibres of the cerebello-spinal fasciculus (direct cerebellar tract) of the same side.

(2) Fibres from the nuclei funiculi gracilis and funiculi cuneati of the same and opposite side (external arcuate fibres).

(3) Fibres to and from the inferior olives of the same and opposite side (cerebello-olivary fibres).

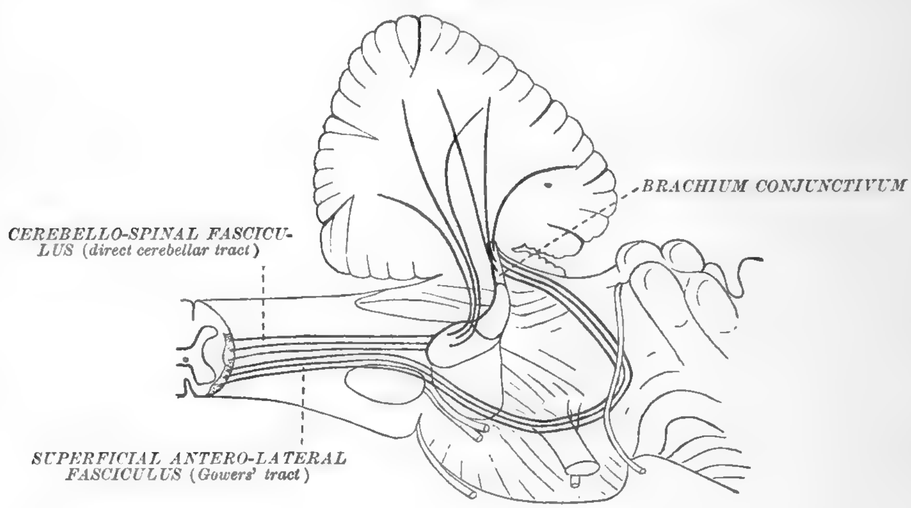
(4) Sensory cerebellar fibres from the nuclei of termination of the vagus, glossopharyngeus, vestibularis, and trigeminus, and from the cells of the reticular formation.

(5) Descending fibres to the motor nuclei of these nerves, except that of the trigeminus, and fibres descending into the intermediate and anterior marginal fasciculi of the spinal cord, the latter being in large part interrupted by cells in the nucleus of the vestibular nerve.

The ascending fibres of the restiform body are distributed to the cortex of the vermis, the nucleus fastigii, the nucleus dentatus, nucleus emboliformis, and nucleus globosus.

Very few if any of the fibres ascending the cord in *Gowers' tract* enter the cere-

Fig. 605.—Diagram showing the Rhombencephalic Course of Gowers' Tract and the Direct Cerebellar Tract.



bellum by way of the restiform body. This tract (the superficial antero-lateral fasciculus of the spinal cord) ascends the medulla, dispersed in the reticular formation, and therefore in a more ventral position than that of the direct cerebellar tract. In this position it becomes enclosed by the fibres of the pons, and so it passes upwards around the lateral lemniscus to the brachium conjunctivum, and there turns back to enter the cerebellum by way of the anterior medullary velum. Certain clinical phenomena, probably purely psychological, have been alleged to indicate that some of the fibres of Gowers' tract pass on to the cerebrum instead of turning in the medullary velum to enter the cerebellum.

The dorsal part of a transverse section through the *upper part* of the pons contains the **brachia conjunctiva** (superior cerebellar peduncles) instead of the restiform bodies or inferior peduncles. Instead of the cerebellum forming the roof of the fourth ventricle, in this region the roof is formed by the anterior medullary velum bridging the space between the two brachia conjunctiva. Adhering upon the medullary velum is the **lingula cerebelli**—the ventral extremity of the superior vermis. This is the only portion of the cerebellum attached to this region.

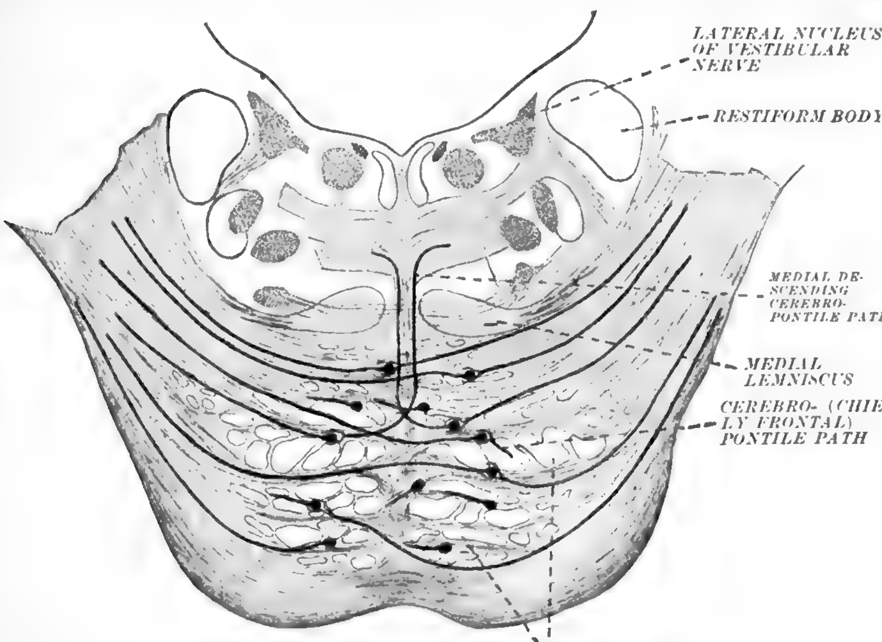
The lemniscus (fillet) is found more lateral than at the inferior border of the pons, and is divided into the *medial lemniscus* and *lateral lemniscus* proper. The lateral lemniscus has shifted dorsally until in this region it courses in the dorso-

lateral margin of the section external to the brachium conjunctivum. The mesencephalic root of the trigeminus occurs in the dorso-lateral margin of transverse sections through this region, and this is the only one of the cranial nerves represented here.

The transverse fibres of the ventral part of the section (pons proper), and therefore the brachia pontis, consist of fibres coursing in opposite directions. Many are fibres which are outgrowths of the Purkinje cells of the cortex of the cerebellar hemispheres, and pass either directly to the hemisphere of the opposite side or turn upwards in the raphe to course longitudinally in the brain-stem both towards the spinal cord and towards the mesencephalon. Others terminate in the grey substance of the pons. Others are fibres which arise in the grey substance of the pons and pass to the cerebellar hemispheres, and still others are the cerebro-pontile fibres, chiefly from the temporal lobes.

The **grey substance of the pons (nuclei pontis)** occurs quite abundantly. At the inferior border of the pons it is found concentrated about the then more accumulated bundles of the emerging pyramids, and serial sections show it to be a

FIG. 606.—DIAGRAM SHOWING CONNECTIONS OF THE FIBRES OF THE PONS.
The plane of the section is obliquely transverse or parallel with the direction of the brachia pontis.



direct upward continuation of the arcuate nuclei of the medulla oblongata below. Higher up it is dispersed throughout the central area in the interspaces between the transverse pontile and longitudinal pyramidal fasciculi. A large portion of the nerve-fibres passing through it are thought to be interrupted by its cells, which thus serve as links in some of the neurone chains represented by the fibres of the pons. Of the more important of such relations, the following are said to exist:—

(1) Fibres which arise in the cortex of one cerebellar hemisphere and terminate about cells of the nucleus pontis of the same and opposite side of the mid-line. These cells give off axones which pass to the other cerebellar hemisphere. In this relation the nuclei pontis are analogous to the arcuate nuclei, save that the cerebellar fibres interrupted in the former are connected with the cerebellum by way of the brachia pontis instead of the restiform bodies.

(2) Certain of the descending cerebro-pontile fibres terminate about cells of the nuclei pontis. Such cells give off fibres which probably, for the most part, pass to the cerebellar hemispheres, the impulses from the cerebral hemisphere of one side being conveyed chiefly to the opposite cerebellar hemisphere.

Of the cerebro-pontile paths, the **frontal pontile path** (Arnold's bundle) is described as arising in the cortex of the frontal lobe, passing in the anterior portion of the internal capsule down into the medial part of the base of the cerebral peduncle, and terminating in the grey substance of the pons. The descending **temporal pontile path,** sometimes called Türk's bundle, arises in the cortex of the temporal lobe, occupies the posterior portion of the internal capsule, lies lateral in the pyramidal portion of the cerebral peduncle, and terminates in the grey substance of the pons. The total area in transverse section of the pyramidal fasciculi as they enter the pons above is considerably greater than that which they possess as they emerge as the pyramids of the medulla below. The difference is considered very appreciably greater than can be explained as due to the loss of pyramidal fibres supplied to the nuclei of origin of the cranial nerves lying within the level of the pons, and the additional difference is explained as due to the termination within the pons of the cerebro-pontile paths.

THE CEREBRUM

THE MESENCEPHALON

The mesencephalon or mid-brain is that small portion of the encephalon which is situated between and connects the rhombencephalon below with the prosencephalon above. It is continuous with the isthmus rhombencephali, and occupies the tentorial notch, the aperture of the dura mater which connects the meningeal cavity containing the cerebellum with that occupied by the prosencephalon. Its greatest length is about 18 mm., and it is broader ventrally than dorsally. Its dorsal surface is hidden by the overlapping occipital lobes of the cerebral hemispheres. It consists of—(1) the **lamina quadrigemina,** a plate of mixed grey and white substance which goes over lateralwards and below into (2), the **cerebral peduncles** (crura) and their tegmental structures, and it contains (3), the *nuclei of origin* of the *trochlear* and *oculomotor* nerves. It arises from thickenings of the walls of the middle cerebral vesicle of the embryo, the lamina quadrigemina arising from the dorsal or alar lamina of this portion of the neural tube, while the basal lamina thickens to form the cerebral peduncles. By means of the lamina quadrigemina roofing it over, the neural canal throughout the mesencephalon retains its tubular form and is known as the **aquæductus cerebri** (Sylvii), connecting the cavity of the fourth ventricle below with that of the third ventricle above.

External features.—*Dorsal surface.*—The lamina quadrigemina shows four well-rounded elevations, the **corpora quadrigemina,** divided by a flat median groove crossed at right angles by a transverse groove. The anterior pair of these, the *superior quadrigeminate bodies* or *superior colliculi,* are larger though less prominent than the inferior pair or *inferior colliculi.* Each colliculus is continued laterally and upwards into its arm or brachium. The **inferior brachium** proceeds from the inferior colliculus, disappears beneath and is continuous into the **medial geniculate body,** and enters the thalamus. The **superior brachium** proceeds from the superior colliculus, disappears between the medial geniculate body and the overlapping pulvinar of the thalamus, and becomes continuous with the **lateral geniculate body** and thus with the lateral root of the optic tract.

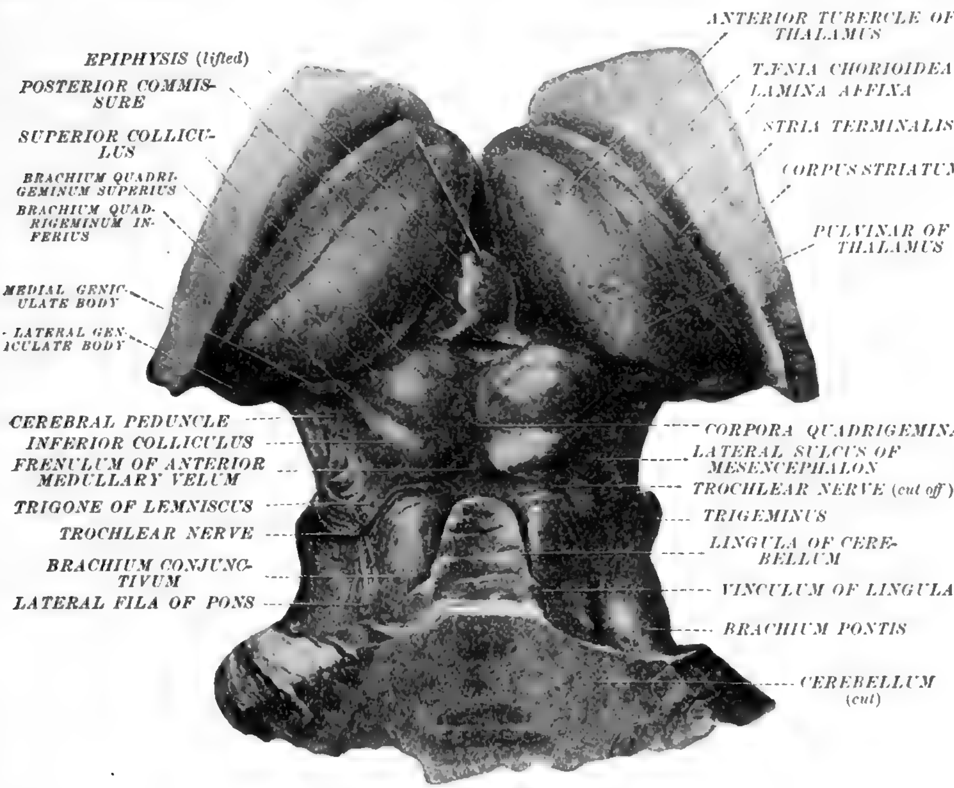
The geniculate bodies are rounded elevations of grey substance which arise as detached portions of the thalami, and therefore belong to the thalamencephalon rather than to the mesencephalon. The superior quadrigeminate body or superior colliculus and the lateral geniculate body are a part of the *optic apparatus*, while the inferior colliculus and the medial geniculate body belong chiefly to the *auditory apparatus* (see Central Connections of Cochlear Nerve). Just as the cochlear nerve is connected by a few fibres with the superior colliculus, so do some fibres from the optic tract pass into the inferior colliculus. Also some fibres from the optic tract (mesial root) are said to terminate in the medial geniculate body. Resting in the broadened medial groove between the superior quadrigeminate bodies lies the non-nervous **epiphysis** or pineal body. This also belongs to the thalamencephalon. Under the stem of the epiphysis is a strong transverse band of white substance crossing the mid-line as a bridge over the opening of the aquæductus cerebri into the third ventricle.

This is the **posterior commissure** of the cerebrum, and contains commissural fibres arising in both the thalamencephalon and mesencephalon. The triangular area bounded by the stem of the epiphysis, the thalamus, and the superior colliculus with its brachium, is known as the **habenular trigone.**

Inferiorly, the lamina quadrigemina is continuous with the brachia conjunctiva or superior cerebellar peduncles, and with the anterior medullary velum which bridges between the mesial margins of these peduncles. The narrowed upper end of the velum, the part directly below the inferior quadrigeminate bodies, is thickened into a well-defined white band known as the **frenulum veli.** From the lateral margins of this band on each side and just below the inferior quadrigeminate bodies emerge the **trochlear nerves** (the fourth pair of cranial nerves), and the increased thickness of the band is largely due to the decussation of this pair of nerves taking place within it.

The brachium conjunctivum, together with the inferior and superior colliculi of each side, form a marked ridge which results in the *lateral sulcus* of the mesencepha-

Fig. 607.—Dorsal Surface of Mesencephalon and Adjacent Parts. (After Spalteholz.)



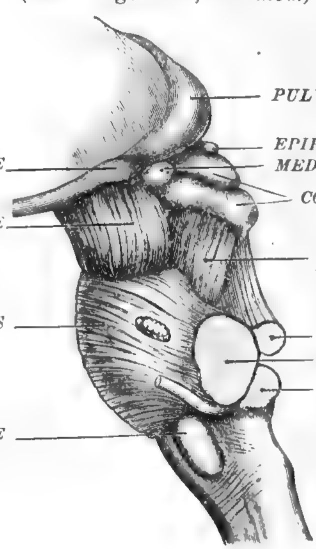
lon, a lateral depression between the base of this ridge and the cerebral peduncle below and continuous into the transverse sulcus of the superior border of the pons. The ridge is thickened laterally by the lateral lemniscus, which is disposed as a band of white substance passing obliquely upwards from the brachium pontis, applied to the lateral surface of the brachium conjunctivum and which enters the lateral margin of the mesencephalon.

The **ventral surface** of the mesencephalon is formed by the **cerebral peduncles** (crura), two large bundles of white substance which are close to one another at the superior margin of the pons, but immediately diverge at a wide angle, producing the **interpeduncular fossa,** and in so doing pass upwards and lateralwards to disappear beneath the optic tracts (fig. 580). The *posterior recess* of the interpeduncular fossa extends slightly under the superior margin of the pons, while its *anterior recess* is occupied by the corpora mammillaria of the prosencephalon. The triangular floor of the fossa is the **posterior perforated substance,** a greyish area presenting numer-

ous openings for the passage of blood-vessels. It is divided by a shallow median groove and is marked off from the inner surface of each peduncle by the *oculomotor sulcus*, out of which emerge the roots of the **oculomotor nerves.** The ventral surface of each peduncle is rounded and has a somewhat twisted appearance, indicating that its fibres curve from above medianwards and inwards. Sometimes two small, more or less transverse bands of fibres may be noted crossing the peduncle—an inferior, the *tænia pontis*, and a superior, the *transverse peduncular tract*. The inferior represents detached fibres of the pons; the superior appears to be derived from the quadrigeminate bodies. Since it is well developed in the cat, dog, sheep, and rabbit, but is absent or little marked in the mole, it is supposed to be concerned with the optic apparatus.

Internal structure.—Transverse sections of the mesencephalon throughout are composed of—(1) a *dorsal part*, consisting of the lamina quadrigemina or the grey substance of the corpora quadrigemina, with the strata and bundles of nerve-fibres connected with them, and the abundant central grey substance surrounding the aqueduct; (2) a *tegmental part*, consisting of the upward continuation of the reticular formation of the medulla oblongata and that of the dorsal (tegmental) portion of the pons region, to which are added the superior cerebellar peduncles and the red nuclei

Fig. 608.—Diagram of Lateral View of Mesencephalon and Adjacent Structures. (After Gegenbaur, modified.)



of the tegmentum in which these peduncles terminate; (3) a paired *ventral part*, the cerebral peduncles, each of which consists of a thick, pigmented stratum of grey substance, the *substantia nigra*, spread upon the large, superficial, and somewhat crescentic tract of white substance known as the *basis* of the peduncle.

The cerebral peduncles correspond to the longitudinal or pyramidal fasciculi of the pons and medulla. Likewise the lemniscus and the medial longitudinal fasciculus of the medulla and pons continue through all sections of the mesencephalon.

The **central grey substance** is a continuation of the central grey substance of the spinal cord and the similar stratum of the medulla and that which immediately underlies the ependyma of the fourth ventricle. As in the spinal cord and medulla, it is largely composed of gelatinous substance. It is much more abundant in the mesencephalon, and in sections appears as a circumscribed area comparatively void of nerve-fibres.

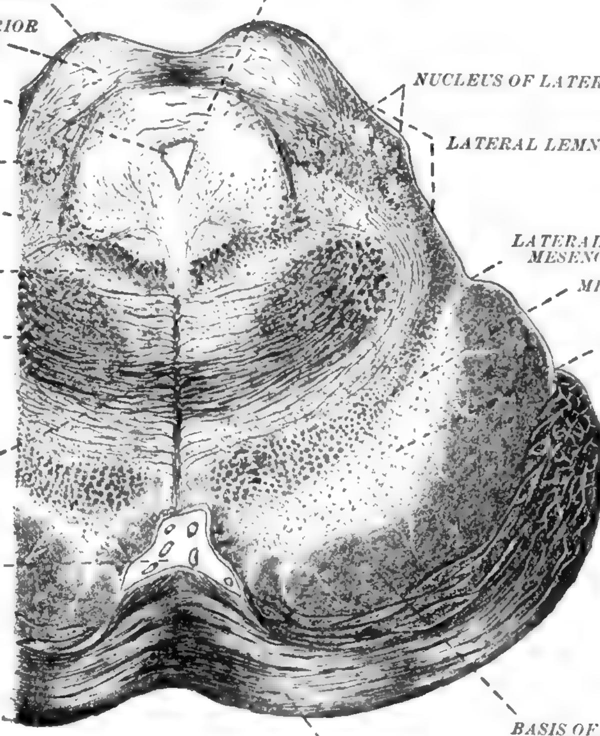
The nucleus of the *mesencephalic root of the trigeminus* may likewise be traced throughout the mesencephalon. It consists of a few small bundles of fibres surrounding a thin strand of nerve-cells of the motor type which give origin to its fibres. It courses downwards close to the lateral margin of the central grey substance, and is quite small at its beginning in the extreme superior part of the mesencephalon, but as it descends towards the exit of its fibres from the pons as a part of the motor root

of the trigeminus, it increases slightly in size, due to the progressive addition of fibres. Its nucleus also increases slightly in bulk in approaching the region of the principal motor nucleus of the trigeminus. The sensory nucleus (nucleus of termination) of the trigeminus probably does not extend appreciably into the mesencephalon.

The nuclei of the trochlear and oculomotor nerves form a practically continuous column of nerve-cells extending close to the mid-line and ventral to the aquæductus cerebri. They are in line with the nuclei of origin of the abducens and hypoglossus, and, like them, may be regarded as an upward continuation of the ventral group of the cells of the ventral horn of the spinal cord. The portion of the column giving origin to the oculomotor nerve is considerably larger than that of the trochlear.

A transverse section through the inferior quadrigeminate bodies involves a portion of the decussation of the brachia conjunctiva and the nuclei of origin of the trochlear nerves, while a transverse section through the superior quadrigeminate

Fig. 609.—Transverse Section Through the Inferior Quadrigeminate Bodies.



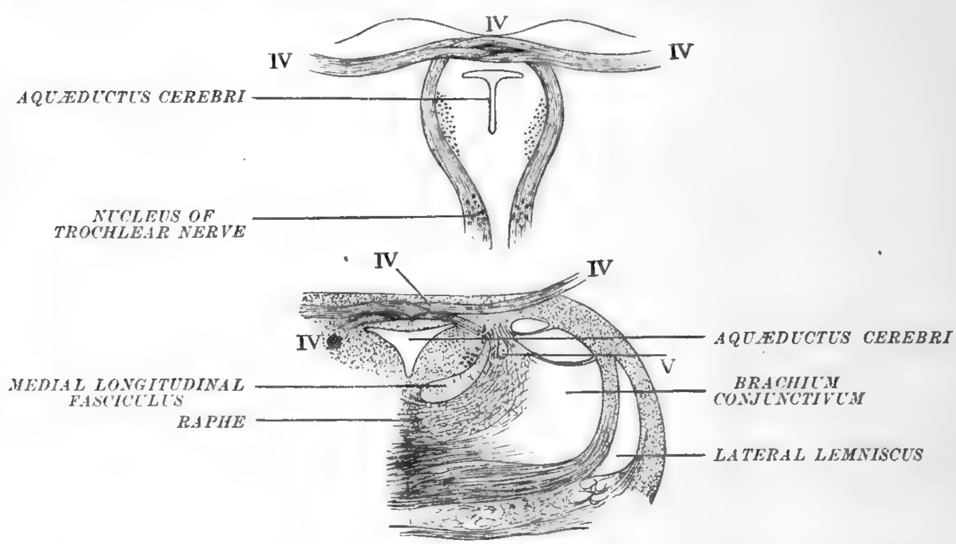
bodies passes through the red nuclei of the tegmentum and the nuclei of origin of the oculomotor nerves. The latter section will also involve the brachia of the inferior quadrigeminate bodies and the medial geniculate bodies connected with them.

The **trochlear or fourth nerve** is the smallest of the cranial nerves, and is the only one which makes its exit from the dorsal surface of the brain, as well as the only one whose fibres undergo a total decussation. Its nucleus of origin is situated beneath the inferior quadrigeminate bodies in the ventral margin of the central grey substance, quite close to the mid-line and to its fellow nucleus of the opposite side, and it is closely associated with the dorso-mesial margin of the medial longitudinal fasciculus. Its fibres pass outwards and dorsalwards, curving around the margin of the central grey substance, mesial to the mesencephalic root of the trigeminus. As the root curves towards the mid-line in the dorsal region just beneath the inferior quadrigeminate bodies, it turns sharply and courses inferiorly to approach the surface

in the superior portion of the anterior medullary velum. In this it meets and undergoes a total decussation with the root of its fellow nerve, and then emerges at the inner margin of the superior cerebellar peduncle of the opposite side. Having emerged, it then passes ventrally around the cerebral peduncle, and thence pursues its course to the superior oblique muscle of the eye.

The **oculomotor or third nerve,** like the trochlear, is purely motor. It is the largest of the eye-muscle nerves. It supplies in all seven muscles of the optic apparatus:—two intrinsic, the sphincter iridis and the ciliary muscle, and five extrinsic. Of the latter, the levator palpebræ superioris is of the upper eyelid, while the remaining four, the superior, internal, and inferior recti and the obliquus inferior, are attached to the bulb of the eye. As is to be expected, its nucleus of origin is larger and much more complicated than that of the trochlear nerve. Practically continuous with that of the trochlear below, the nucleus is 5 or 6 mm. in length and extends anteriorly a short distance beyond the bounds of the mesencephalon into the grey substance by the side of the third ventricle. It lies in the ventral part of the central grey substance, and is very intimately associated with the medial longitudinal fasciculus. Its thickest portion is beneath the summit of the superior quadrigeminate body. The root-fibres leave the nucleus from its ventral side and

Fig. 610.—Diagrams showing the Course of Origin of the Trochlear Nerves. (Stilling.) The upper figure shows roughly the entire central course of the fourth nerves ; the lower represents their region of exit in transverse section.



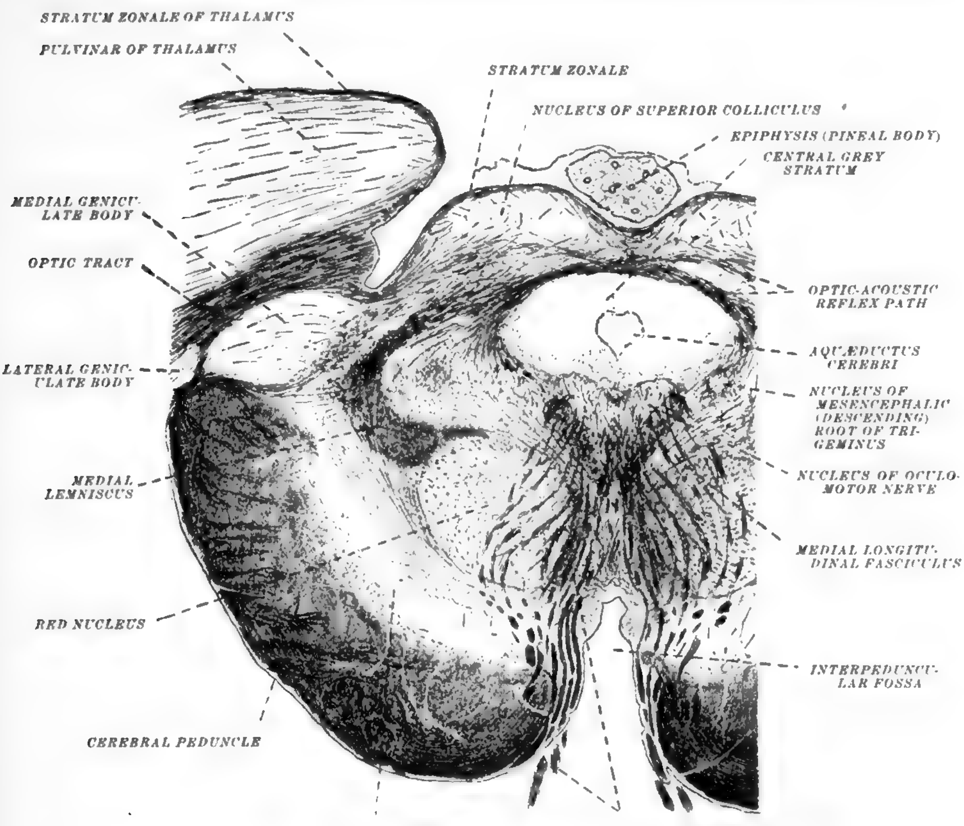
collect into bundles which pass through the medial longitudinal fasciculus and course ventrally to the mesial portion of the substantia nigra, where they emerge in from six to fifteen rootlets which blend to form the trunk of the nerve in the oculomotor sulcus. Those bundles which arise from the more lateral portion of the nucleus course in a series of curves through the substance of the red nucleus below and, in the substantia nigra, join those which pursue the more direct course. The trunk thus assembled passes outwards around the mesial border of the cerebral peduncle.

A portion of the fibres of the oculomotor nerve upon leaving the nucleus decussate in the tegmentum immediately below and pass into the nerve of the opposite side, in which they are believed to be distributed to the opposite internal rectus muscle. The cells of the nucleus have been variously grouped and subdivided with reference to the different muscles supplied by the nerve. Perlia has divided them into eight cell-groups. The nucleus may be more easily considered as composed of an inferior and a superior group. The inferior group consists of a long lateral portion continuous with the nucleus of the trochlear nerve below, and a smaller medial portion, situated in the medial plane and continuous across the mid-line with its fellow of the opposite side. The superior group consists of cells of smaller size than the inferior, and is known as the *nucleus of Edinger and Westphal.* It is believed to give origin to the

fibres which, by way of the ciliary ganglion, supply the two intrinsic muscles concerned, viz., the ciliary muscle and the sphincter iridis.

The nucleus of the oculomotor is connected with the remainder of the optic apparatus—(1) by way of the neurones of the superior quadrigeminate body with the optic tract (retina) and the occipital part of the cerebral cortex; (2) by way of the medial longitudinal fasciculus with the nuclei of the trochlear and abducens (the latter making possible the co-ordinate action of the external and internal recti for the conjugate eye movements produced by these muscles), and with the nucleus of the facial (associating the innervation of the levator palpebræ with that of the orbicularis oculi); (3) with the nuclei of termination of the sensory nerves, especially the auditory, by way of the lemniscus and medial longitudinal fasciculus. It is probably connected with the cerebellum by way of the brachia conjunctiva and red nuclei.

FIG. 611.—TRANSVERSE SECTION THROUGH LEVEL OF SUPERIOR QUADRIGEMINATE BODIES.



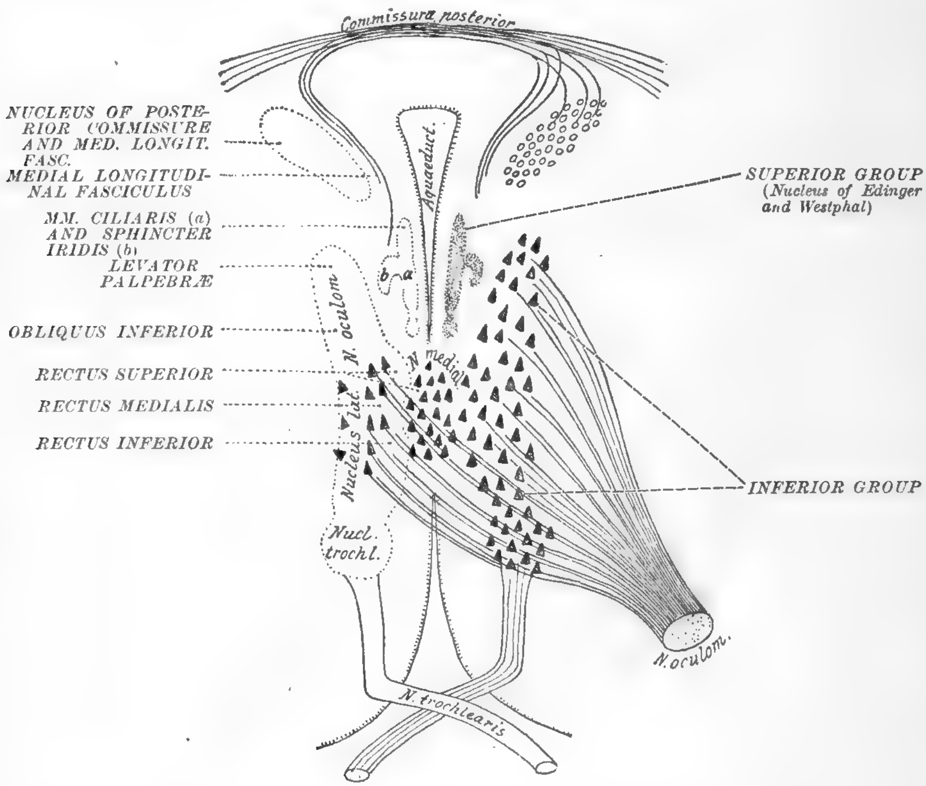
The eminence representing the **inferior quadrigeminate body** proper consists of an oval mass of grey substance, the *nucleus of the inferior colliculus*, containing numerous nerve-cells, most of which are of small size. A thin superficial lamina of white substance, the **stratum zonale,** forms its outermost boundary, and fibres from the lateral lemniscus enter it laterally and from below. Near the lateral margin of the central grey substance occurs the beginning of the *inferior brachium*, a bundle containing fibres to and from the medial geniculate body and the thalamus.

The **lemniscus** at this level is considered in two parts. The more lateral portion of the horizontal arrangement assumed in the pons has here spread dorso-laterally, and occupies a position in the lateral margin of the section, and is known as the **lateral lemniscus,** while the medial portion which remains practically horizontal in the tegmentum is distinguished as the **medial lemniscus.** (See fig. 609.) In the upper portion of the lateral lemniscus occurs a small, scattered mass of grey sub-

stance, the *nucleus of the lateral lemniscus,* in which many of its fibres are interrupted.

The upper and greater portion of the **lateral lemniscus** with its nucleus belongs to the auditory apparatus, being connected with the nucleus of termination of the cochlear nerve, chiefly of the opposite side. (See fig. 601.) A large part of the fibres of this portion terminate in the inferior quadrigeminate bodies. Many of these enter at once the nucleus of the body of the same side, and disappear among its cells; others cross the mid-line to the quadrigeminate body of the opposite side. In crossing, some pass superficially and thus contribute to the stratum zonale, while others pass either through the nucleus or below it and cross beneath the floor of the median groove between the stratum zonale and the dorsal surface of the central grey substance, forming there an evident decussation with similar fibres crossing from the opposite side. Most of the fibres arising from the cells of the nucleus of the quadrigeminate body either pass by way of the inferior brachium to the medial geniculate

Fig. 612.—Diagram of Longitudinal Section of Nucleus of Oculomotor Nerve. (After Edinger.)



body and the thalamus, or pass ventrally to terminate in the nucleus of origin of the trochlear nerve. Another portion of the lateral lemniscus passes obliquely forwards in company with the inferior brachium, and terminates in the medial geniculate body. Thus the inferior quadrigeminate bodies with their brachia and the medial geniculate bodies and a large portion of the lateral lemniscus are concerned with the sense of hearing.

Practically all the remainder of the lateral lemniscus terminates in the nucleus, or stratum cinereum, of the superior quadrigeminate body of the same and opposite sides. They approach the nucleus from below, and contribute to the well-marked band of fibres coursing on the dorso-lateral margin of the central grey substance, and known as the '*optic-acoustic reflex path*' (fig. 611).

The **medial lemniscus** arises in the medulla oblongata from the nuclei (of termination) of the funiculus gracilis and funiculus cuneatus of the opposite side, and likewise from the nuclei of termination of the sensory roots of the cranial nerves. It

is, therefore, a continuation of the central sensory pathway conveying the general bodily sensations into the prosencephalon. In passing the superior quadrigeminate body it contributes fibres to its nucleus. The remaining part, coursing still more laterally than below, passes into the hypothalamic grey substance, in the lateral portion of which most of its fibres terminate. From the thalamic region the impulses borne thither by the lemniscus are conveyed by way of the internal capsule and corona radiata to the gyri of the somæsthetic area of the cerebral cortex.

The **basis** (pes) **pedunculi** comprises the great descending pathway from the cerebral cortex, and thus is continuous with the internal capsule of the telencephalon. The principal components of each basis pedunculi are as follows:—(1) The *pyramidal fibres*, which occupy the middle portion of the peduncle and comprise three-fifths of its bulk, and which are outgrowths of the giant pyramidal cells of the somæsthetic area of the cerebral cortex. These supply 'voluntary' impulses to the motor nuclei of the cranial nerves, form the pyramids of the medulla, and are distributed to the ventral horn cells of the spinal cord. (2) The *frontal pontile fibres*, which course in the mesial part of the peduncle from the cortex of the frontal lobe to their termination in the grey substance of the pons. (3) The *temporal pontile fibres*, which run in the lateral portion of the peduncle from their origin in the temporal lobe to their termination in the grey substance of the pons.

The **substantia nigra** is continuous with the grey substance of the pons and of the reticular formation below, and with that of the hypothalamic region above. Its remarkable abundance begins at the superior border of the pons, and it conforms to the crescentic inner contour of the basis pedunculi, sending numerous processes which occupy the inter-fascicular spaces of the latter. It contains numerous deeply pigmented nerve-cells, which in the fresh specimen give the appearance suggesting its name. Its anatomical significance is not well understood. It is known that some fibres of the medial lemniscus terminate about its cells instead of in the hypothalamus higher up, and Mellus has found in the monkey that a large portion of the pyramidal fibres arising in the thumb area of the cerebral cortex are interrupted in the substantia nigra. It is probable that other fibres of the basis pedunculi also terminate here.

The **brachia conjunctiva** or superior cerebellar peduncles, in passing from their origin in the dentate nuclei, lose their flattened form and enter the mesencephalon as rounded bundles. In the tegmentum, under the inferior colliculi, the two brachia come together and undergo a sudden and complete decussation. Through this decussation the fibres of the brachium of one side pass forwards to terminate, most of them, in the red nucleus of the tegmentum (nucleus ruber) of the opposite side (fig. 589).

The **red nuclei** are two large, globular masses of nerve-cells situated in the tegmentum under the superior quadrigeminate bodies. At all levels they are considerably mixed with the entering bundles of the brachia conjunctiva, and they contain a pigment which in the fresh condition gives them a reddish colour, suggesting their name. They receive in addition descending fibres from the cerebral cortex and from the nuclei of the corpus striatum. From the cells of each red nucleus arise fibres which pass—(1) into the thalamus and to the telencephalon (prosencephalic continuation of the cerebellar path), and (2) fibres which descend into the spinal cord, the 'rubro-spinal tract,' in the intermediate fasciculus (fig. 571). The latter cross from the red nucleus of the opposite side and descend in the tegmentum. The red nuclei are also in relation with the *fasciculus retroflexus* of Meynert, which belongs to the inter-brain.

The **superior quadrigeminate bodies (superior colliculi)** are phylogenetically more important than the inferior. In certain of the lower vertebrates they are enormously developed and in most of the mammals they are relatively larger and appear more complicated in structure than in man. They are concerned almost wholly with the visual apparatus.

The *nucleus* of the superior colliculus is of somewhat greater bulk than that of the inferior. It is capped by a strong *stratum zonale* (fig. 611), which has been described as composed chiefly of retinal fibres, passing to it from the optic tract by way of the superior brachium, but, since Cajal found in the rabbit that extirpation of the eye is followed by very slight degeneration of the stratum zonale, it is probable that it is composed of other than retinal fibres—possibly fibres from the occipital cortex and fibres arising within the nucleus itself. The nucleus is separated from the central grey

substance by a well-marked band of fibres, the *stratum album profundum.* This contains fibres from two sources:—(1) fibres from the lateral and medial lemnisci, which approach the nucleus from the under side, some to terminate within it, others to cross to the nucleus of the opposite side; (2) fibres which arise within the nucleus and course ventrally around the central grey substance, both to terminate in the nucleus of the oculomotor nerve and to join the medial longitudinal fasciculus and pass probably to the nuclei of the trochlear and abducens. The optic fibres proper approach the nucleus by way of the superior brachium, and are dispersed directly among its cells; only a small proportion of them cross over to terminate in the nucleus of the opposite side. They consist of two varieties:—(1) retinal fibres which arise in the ganglion-cell layer of the retina and enter the superior brachium at its junction with the lateral root of the optic tract, and (2) fibres from the visual area of the occipital lobe of the cerebral hemisphere. Sometimes the optic fibres in their course within the nucleus of the superior colliculus form a more or less evident stratum near the stratum album profundum. This is known as the *stratum opticum* (stratum album medium). The portion of the nucleus between this stratum and the stratum zonale is called the *stratum cinereum.*

The fibres entering the nucleus from the lateral lemniscus probably all represent auditory connections. The stratum album profundum, composed of the lemniscus fibres and fibres from cells of the nucleus and the stratum opticum together, form the so-called **'optic-acoustic reflex path'** (fig. 611).

From the various studies that have been made it appears that the superior colliculus of the corpora quadrigemina is merely the central reflex organ concerned in the control of the eye muscles—eye muscle reflexes which result from retinal and cochlear stimulation. Fibres from its nucleus to the visual area of the occipital cortex have been claimed for certain mammals, but in man the superior colliculus may be entirely destroyed without disturbance of the perception of light or color.

In the level of the anterior part of the superior colliculus the fibres which arise from the cells of its nucleus and course ventrally in the stratum album profundum collect into a strong bundle. This bundle passes ventral to the medial longitudinal fasciculus and, in the space between the two red nuclei, it forms a dense decussation with the similar bundle from the opposite side. In decussating the fibres turn in spray-like curves downwards and soon join the medial longitudinal fasciculus. This is the **'fountain decussation.'** (Forel.)

There is abundant evidence that fibres arising in the corpora quadrigemina descend into the spinal cord. Various studies make it appear that at least part of these are fibres from the fountain decussation, and that these course through the medulla oblongata in the ventral part of the medial longitudinal fasciculus, and thence descend into the cord, probably no further than the cervical region, in the 'quadrigemino-thalamus path' (fig. 571). The termination of these crossed fibres about those ventral horn cells of the cervical cord which send fibres through the rami communicantes probably establishes the pathway by which the superior quadrigeminate bodies, and indirectly the retina, are connected with the cervical sympathetic ganglia, and by which may be explained the disturbances in pupillary contraction induced by lesions of the lower cervical cord.

The medial geniculate body and the medial root of the optic tract, which runs into the former, probably have nothing to do with the functions of the optic apparatus. Both remain intact after extirpation of the eyes. The medial root of the optic tract is apparently nothing more than the beginning of *Gudden's commissure,* a bundle passing by way of the optic tract, connecting the medial geniculate body of one side with that of the other side.

The **medial longitudinal fasciculus** (posterior longitudinal fasciculus) is continuous with the ventral fasciculus proprius and the sulco-marginal fasciculus of the spinal cord, extends throughout the rhombencephalon and mesencephalon, and is represented in the hypothalamic region of the prosencephalon. Deserted by the lemniscus at the inferior border of the pons, it maintains its closely medial position and courses throughout in the immediate ventral margin of the central grey substance of the central canal and floor of the fourth ventricle, and likewise in the ventral margin of the central grey substance of the mesencephalon. The two fasciculi constitute the principal association pathways of the brain-stem, and, true to their nature as such, they are among the first of its pathways to acquire medullation. In the mesencephalon they become two of its most conspicuous tracts, and

their course, in most intimate association with the nuclei of origin of the nerves supplying the eye muscles, suggests what is probably their most important function, viz., that of associating these nuclei with each other and of bearing to them fibres from the nuclei of the other cranial nerves necessary for the co-ordinate action of the muscles of the optic apparatus associated with the functions of these other nerves.

Fibres from each medial longitudinal fasciculus terminate either by collaterals or terminal arborisations about the cells of the motor nuclei of all the cranial nerves, and each nucleus probably contributes fibres to it. It also receives fibres from the nuclei of termination of the sensory nerves. Thus it contains fibres coursing in both directions, and, while it is continually losing fibres by termination, it is being continually recruited and so maintains a practically uniform bulk. Thus, a given lesion never results in its total degeneration. Many of the fibres coursing in it arise from the opposite side of the mid-line. A special contribution of fibres of this kind is received by way of the fountain decussation from the nucleus of the superior colliculus of the opposite side. As noted above, it is in part continuous into the spinal cord. It receives some fibres by way of the posterior commissure of the prosencephalon from a small nucleus common to it and the posterior commissure situated in the superior extension of the central grey substance of the mesencephalon. Van Gehuchten and Edinger describe for it a special nucleus situated beyond this commissure in the hypothalamic region. This nucleus may be explained as receiving impulses from the structures of the prosencephalon which are distributed to the structures below by way of the fasciculus longitudinalis medialis.

As frequently realized in the above, the structures of the mesencephalon are both overlapped by, and are of necessity functionally continuous with, the structures of the next and most anterior division of the encephalon, the prosencephalon.

THE PROSENCEPHALON

The **prosencephalon** or **fore-brain** includes those portions of the encephalon derived from the walls of the anterior of the three embryonic brain-vesicles. In its adult architecture it consists of—(1) the **diencephalon (interbrain)**, comprising the thalamencephalon or the thalami and the structures derived from and immediately adjacent to them, and, in addition, the mammillary portion of the hypothalamic region; (2) the **telencephalon (end-brain)**, comprising the optic portion of the hypothalamic region and the cerebral hemispheres proper. The last mentioned consist of the entire cerebral cortex or superficial mantle of grey substance, including the rhinencephalon, and also the basal ganglia or buried nuclei (corpus striatum), together with the tracts of white substance connecting and associating the different regions of the hemispheres with each other and with the structures of the other divisions of the central system.

EXTERNAL FEATURES OF THE PROSENCEPHALON

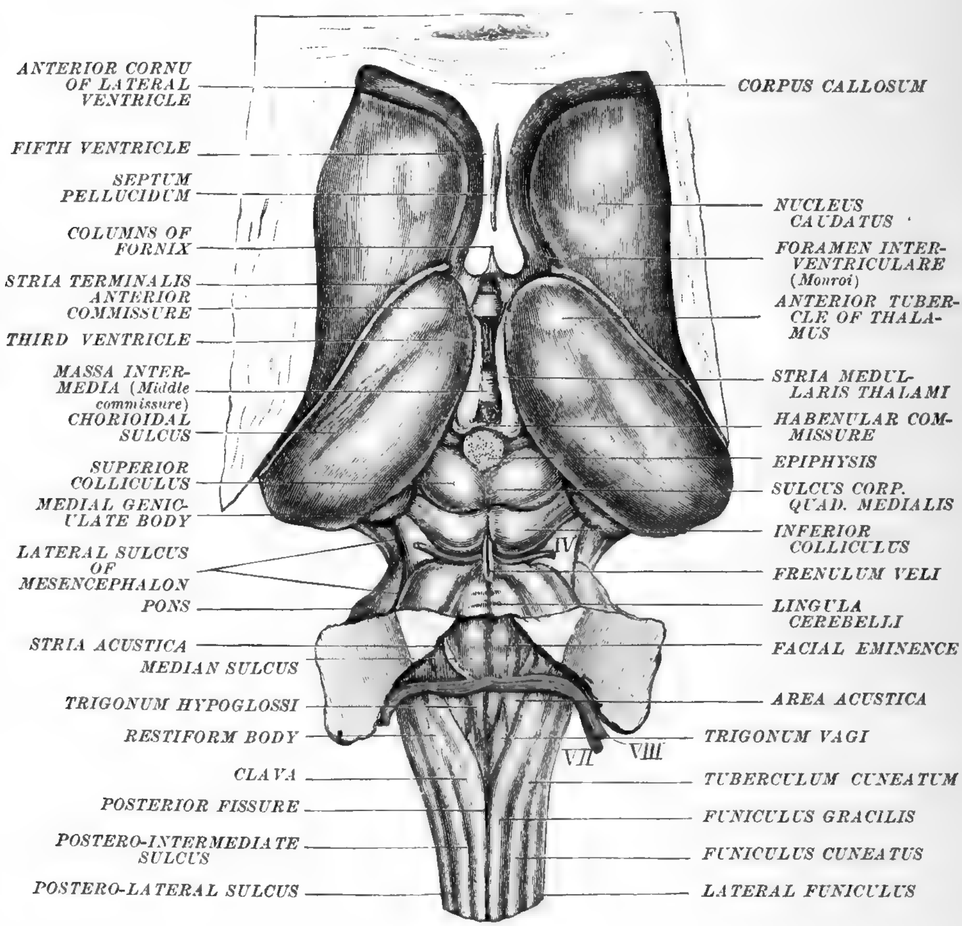
The diencephalon.—The *basal surface* of this division of the brain consists of only the mammillary portion of the hypothalamic region. This comprises—(1) the **corpora mammillaria (albicantia)**, the two rounded projections situated in the anterior part of the interpeduncular fossa, and (2) the **posterior perforated substance** or the small triangle of grey substance forming the floor of the posterior part of the third ventricle, and which represents numerous openings for the passage of branches of the posterior cerebral arteries (fig. 616). The hypothalamic portions of the cerebral peduncles might be included. The structures of the optic or remaining portion of the hypothalamus belong to the telencephalon.

The *dorsal surface* of the diencephalon is completely overlapped and hidden by the telencephalon, and covered by the intervening ingrowth of the cerebral meninges, the tela chorioidea of the third ventricle (velum interpositum). These removed, it is seen that the thalami are by far the most conspicuous objects of the diencephalon. They, together with the parts developed in connection with them, are distinguished as the **thalamencephalon.** The thalamencephalon consists of—(1) the *thalami;* (2) the *metathalamus* or geniculate bodies; and (3) the *epithalamus*, comprising the

epiphysis with the posterior commissure below it and the habenular trigone on its either side.

The **thalami** are two ovoid, couch-like masses of grey substance which form the lateral walls of the third ventricle. The cavity of the ventricle is narrow, and quite frequently the thalami are continuous through it across the mid-line by a small but variable neck of grey substance, the **massa intermedia** or middle commissure. The upper surfaces of the thalami are free. The edges of the tela chorioidea of the third ventricle are attached to the lateral part of the surface of each thalamus, and, when removed, leave the *tænia chorioidea* lying in the chorioidal sulcus. Each thalamus is separated laterally from the caudate nucleus of the telencephalon, by a linear continuation of the white substance below, known as the **stria terminalis**

FIG. 613.—DORSAL SURFACE OF DIENCEPHALON WITH ADJACENT STRUCTURES. (After Obersteiner.)

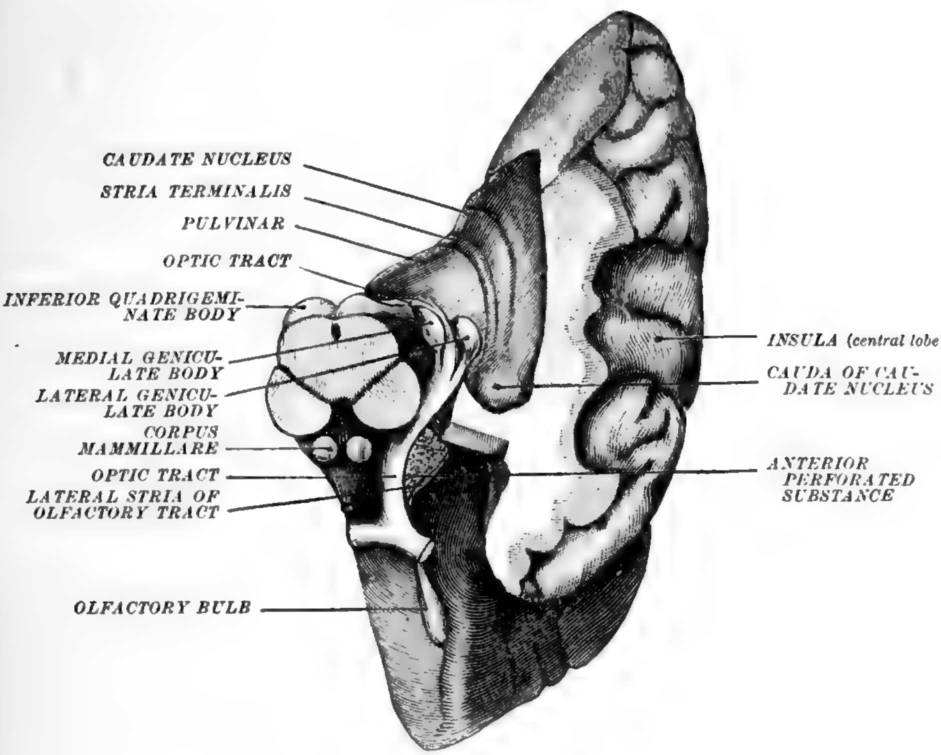


(tænia semicircularis). Like the quadrigemina, each thalamus is covered by a thin capsule of white substance, the **stratum zonale.** The average length of the thalamus is about 38 mm., and its width about 14 mm.; its inferior extremity is directed obliquely outwards. The dorsal surface usually shows four eminences, indicating the position of the so-called nuclei of the thalamus. These are the anterior nucleus or *anterior tubercle*, the *medial nucleus* or tubercle, the *lateral nucleus*, and the *pulvinar*, the tubercle of the posterior extremity. The pulvinar of the human brain is peculiar in the fact that it is so developed as to project inferiorly and slightly overhang the level of the quadrigeminate bodies. The projecting portion assumes relations with the optic tract and the metathalamus.

Both the structures of the **metathalamus,** the lateral and medial geniculate bodies, are connected with the optic tract. As this tract curves around the cerebral peduncle it divides into two main roots. The *lateral geniculate body* receives a large portion of the fibres of the lateral root of the optic tract; the remainder pass under this body and enter the pulvinar of the thalamus. The *medial geniculate body* is connected with the medial root of the optic tract, which root consists largely, not of retinal fibres, as does the lateral root, but of the fibres forming Gudden's commissure (the inferior cerebral commissure).

Of the **epithalamus,** the *epiphysis* (pineal body, conarium) is the most conspicuous external feature. This is an unpaired, cone-shaped structure, about 7 mm. long and 4 mm. broad, which also projects upon the mesencephalon so that its body rests in the groove between the superior quadrigeminate bodies. Its stem

Fig. 614.—Dissection of Brain showing Metathalamus and Pulvinar with Adjacent Structures.



is attached in the mid-line at the posterior extremity of the third ventricle, and therefore just above the posterior commissure of the cerebrum (fig. 607). It is covered by pia mater, and is enclosed in a continuation of the tela chorioidea of the third ventricle. Though it developes as a diverticulum of that portion of the anterior primary vesicle which gives origin to the thalamencephalon, it is wholly a non-nervous structure, other than the sympathetic fibres which enter it for the supply of its blood-vessels.

It consists of a dense capsule of fibrous tissue (pia mater) from which numerous septa pass inwards, dividing the interior into a number of intercommunicating compartments filled with epithelial (ependymal) cells of the same origin as the ependyma lining the ventricles and aqueduct below. Among these cells are frequently found small accretions (brain-sand, acervulus cerebri), consisting of mixed phosphates of lime, magnesia, and ammonia and carbonates of lime. The compartments form a closed system. In function the epiphysis ranks as one of the glands of internal secretion of the body, and it is often referred to as the 'pineal gland.'

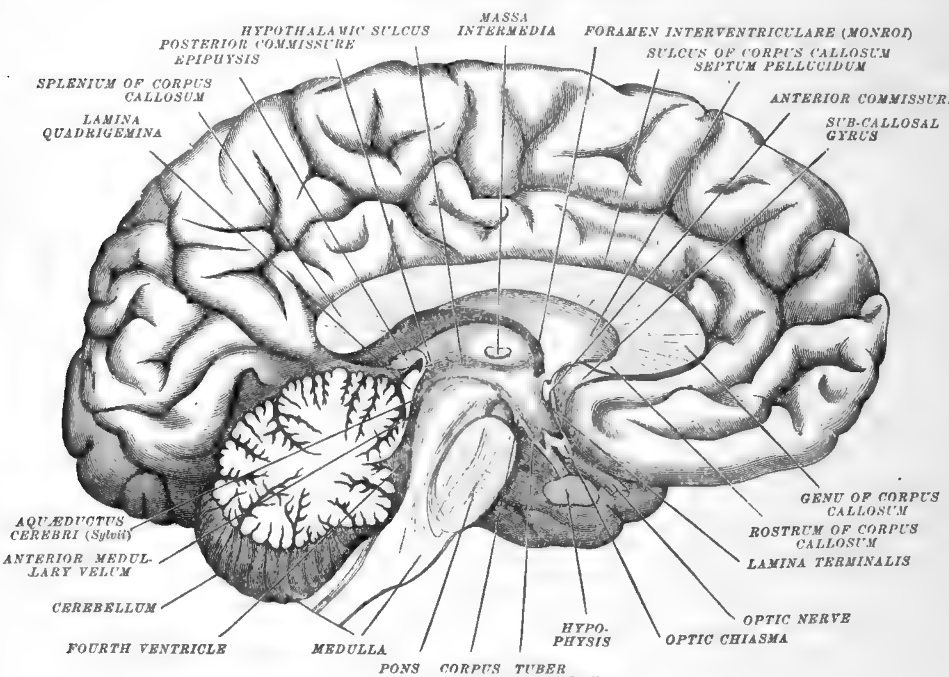
Apparently arising from the base of the epiphysis, but having practically nothing to do with it, are the **striæ medullares of the thalamus** (striæ pineales, pedunculi

conarii). These are two thin bands of white substance which extend from the epiphysis anteriorly upon the thalamus, along the upper border of each lateral wall of the third ventricle, and thus form the boundaries between the dorsal and mesial surfaces of each thalamus. They have been called the *habenulæ*, from their relation to the habenular nucleus, situated in the mesial grey substance below their lower ends. They are continuous across the mid-line in the *habenular commissure*, just below the neck of the epiphysis, and between it and the posterior cerebral commissure (figs. 582 and 613).

The ventro-lateral surface of the thalamencephalon is continuous into the hypothalamic tegmental region, the upward continuation of the tegmental grey substance of the mesencephalon. It is also adjacent to a portion of the internal capsule. Both these relationships, as well as the fibre connections of the diencephalon with the structures above and below it, are deferred until the discussion of the internal structure of the prosencephalon.

The **mesial surface** of the diencephalon allows a better view of the shape and relations of the **third ventricle.** Below the line of the massa intermedia the ven-

FIG. 615.—MESIAL SECTION OF ENTIRE BRAIN, SHOWING MESIAL SURFACE OF DIENCEPHALON AND TELENCEPHALON. (After Henle.)



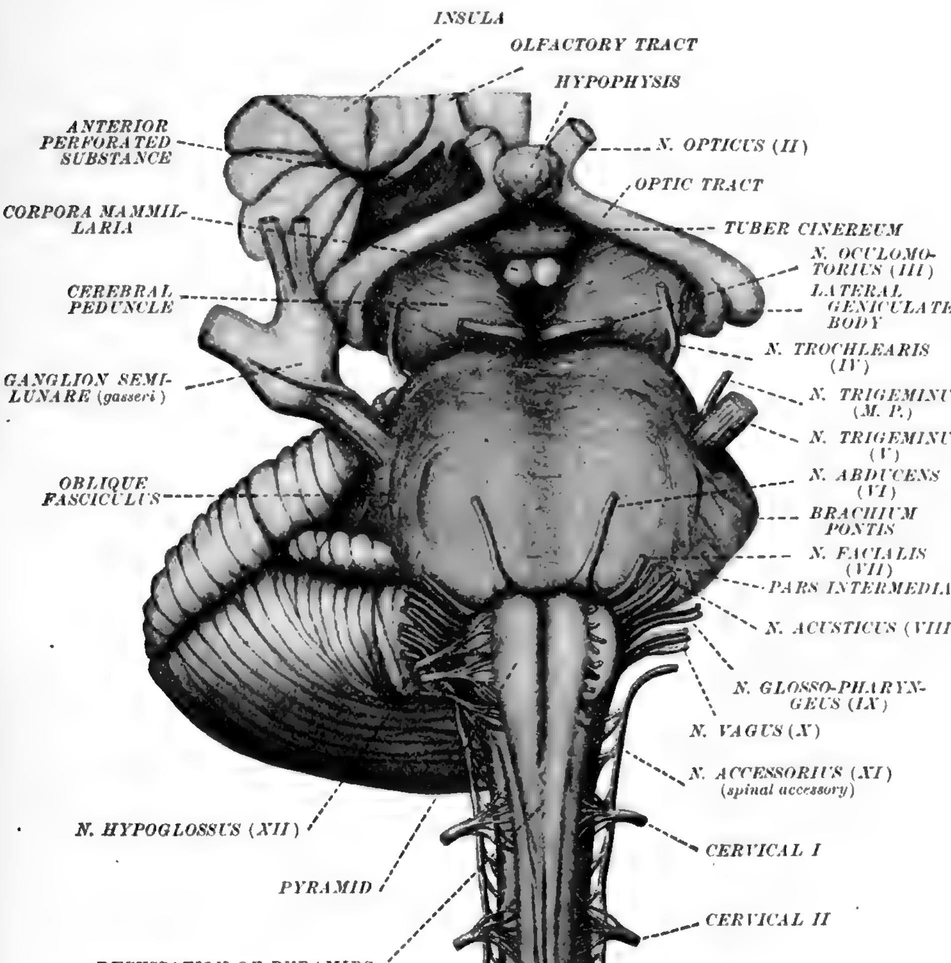
tricle is usually somewhat wider than it is along the upper margins of the thalami. This greater width is occasioned by a groove in the ventromesial surface of each thalamus, known as the **hypothalamic sulcus** (sulcus of Monro). It is along the line of this sulcus that the third ventricle is continuous with the aquæductus cerebri, and thus with the fourth ventricle below, and, likewise, with the two lateral ventricles of the cerebral hemispheres at its anterior end. The latter junction occurs through a small oblique aperture, the **interventricular foramen** (foramen of Monro), one into each lateral ventricle. The dorsal or upper portion of the third ventricle extends posteriorly beneath its tela chorioidea (velum interpositum) to form a small posterior recess about the epiphysis. This is known as the **suprapineal recess.** The anterior and ventral extremity of the third ventricle involves the pars optica hypothalami, which belongs to the telencephalon.

THE TELENCEPHALON.—**External features.**—The **optic portion** of the hypothalamus consists of that small central area of the basal surface of the telencephalon which includes and surrounds the **optic chiasma,** and comprises the

structures of the floor of the anterior and ventral portion of the third ventricle. The area extends anteriorly from the corpora mammillaria in the interpeduncular fossa; and includes the **tuber cinereum** and **hypophysis** behind the optic chiasma, and some of the **anterior perforated substance** in front of it.

The most anterior portion of the third ventricle is in the form of a ventral extension. The wall of this portion is almost wholly non-nervous and quite thin, and thus the cavity of the ventricle is but thinly separated from the exterior of the brain. The front portion of this wall is the **lamina terminalis** and in the ventricular side of the dorsal part of this lamina the **anterior commissure** of the brain

Fig. 616.—Ventral Aspect of Brain-stem Including Mammillary and Optic Portions of the Hypothalamus.



is apparent. The **optic chiasma** lies across and presses into the lower portion of the lamina terminalis, and in so doing produces an anterior recess in the cavity of the ventricle known as the **optic recess.** The posterior and most evident part of this portion of the wall of the third ventricle bulges slightly, giving the outward appearance known as the **tuber cinereum,** and the cavity bounded by this terminates in the **infundibular recess.**

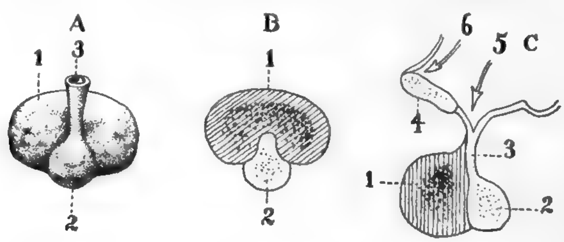
The **tuber cinereum** then is a hollow, conical projection of the floor of the third ventricle, between the corpora mammillaria and the optic chiasma. Its wall is continuous anteriorly with the lamina terminalis and laterally with the anterior perforated substance.

The **infundibulum** is but the attenuated apex of the conical tuber cinereum, and forms the neck connecting it with the hypophysis. It is so drawn out that it is referred to as the stalk of the hypophysis. The cavity of the tuber cinereum (infundibular recess) is sometimes maintained throughout the greater part of the length of the infundibulum, giving it the form of a long-necked funnel. Near the hypophysis the cavity is always occluded.

The **hypophysis cerebri** (pituitary body or gland) is an ovoid mass terminating the infundibulum. It lies in the sella turcica of the sphenoid bone, where it is held down and roofed in by the *diaphragma sellæ,* a circular fold of the dura mater. It consists of two lobes, a large *anterior lobe,* the glandular or buccal lobe, and a smaller *posterior* or *cerebral lobe.* The posterior lobe is enclasped in a concavity of the anterior lobe.

Development.—The posterior or cerebral lobe alone is originally continuous with and a part of the infundibulum. It alone represents the termination of the hollow diverticulum which, in the embryo, grows downwards from that part of the anterior cerebral vesicle which later becomes the third ventricle. The original cavity afterwards becomes obliterated except in the upper part of the infundibulum. It is, therefore, of cerebral origin. The anterior or buccal lobe arises quite differently. It is developed from an upward tubular diverticulum (Rathke's pouch) of the primitive buccal cavity. In the higher vertebrates, including man, its connection with the buccal cavity becomes obliterated as the cartilaginous base of the cranium is consolidated, but in the myxinoid fishes the connection remains patent in the adult. Cut off within the cranial cavity, the embryonic buccal lobe assumes its intimate association with the cerebral lobe. In about the second month of fetal life it begins to develop numerous secondary diverticula which become the epithelial compartments evident in the adult human subject.

FIG. 617.—DIAGRAMS OF THE HYPOPHYSIS CEREBRI. (After Testut.)
A, posterior surface; B. transverse section; C, sagittal section; 1, anterior lobe; 2, posterior lobe; 3, infundibulum; 4, optic chiasma; 5, infundibular recess; 6, optic recess. In C the infundibulum is relatively much shorter than in the actual specimen.



Structure.—The posterior or cerebral lobe retains no organized structure. It may be said to consist of a mass of neuroglia and other fibrous connective tissue with the cells belonging to these and a moderate supply of blood-vessels. The anterior or glandular lobe is probably the functional part of the organ. In addition to its abundant supporting tissue, it consists of compartments lined with two kinds of cuboidal cells—cells of different size and different staining properties. The *principal* or more numerous cells are smaller, with thickly granular cytoplasm. In mixtures containing orange G and fuchsin these cells stain orange, while the *chromophile cells,* the larger and less numerous variety, take the fuchsin deeply. The compartments have an abundant blood supply.

Like the epiphysis, the hypophysis must be regarded as glandular—a gland with internal secretion. In the case of giants and in acromegaly it is usually greatly enlarged. The principal cells increase greatly in number after removal of the thyreoid body.

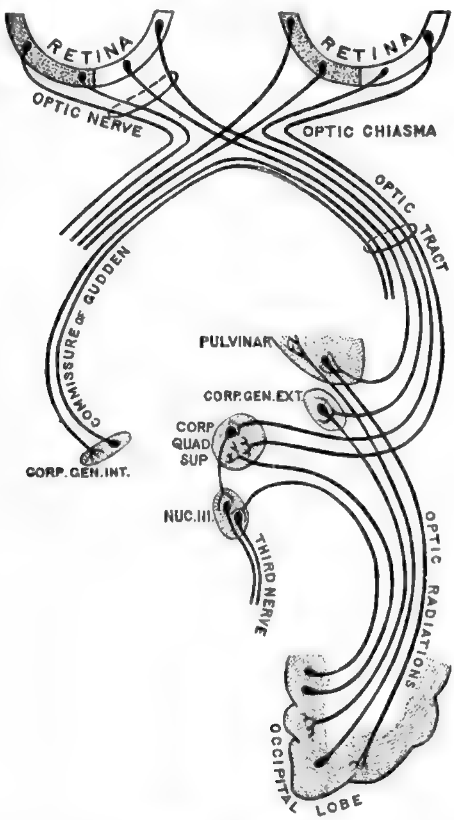
The **optic nerve** is derived from this portion of the telencephalon, though the nuclei of termination of its fibres are chiefly in the thalamencephalon and mesencephalon. The optic apparatus consists of the retinæ and optic nerves, the optic chiasma, the optic tracts, the superior quadrigeminate bodies with their connections with the nuclei of the eye-moving nerves, the metathalamus, the pulvinar of the thalamus, and the visual area of the occipital lobe of the cerebral cortex. The fibres of the optic nerves arise from the cells of the ganglion-cell layer of the retinæ. The fibres which arise in the mesial or nasal halves of each retina cross the mid-line to find their nuclei of termination in the central grey substance of the opposite side, while those from the outer or lateral halves terminate on the same side.

The **optic chiasma** (optic commissure) is functionally independent of the structures of the optic portion of the hypothalamus adjacent to it. It is formed by the approach and fusion of the two optic nerves, and is knit together by the decussating

fibres from the nasal halves of each retina, and, in addition, by the fibres of Gudden's commissure which is contained in it.

Beyond the chiasma the optic fibres continue as the **optic tracts** which course posteriorly around the cerebral peduncles to attain their entrance into the thalamencephalon and mesencephalon. Upon reaching the pulvinar of the thalamus each optic tract divides into two roots, a lateral and mesial. The *lateral root* contains practically all of the true visual fibres—fibres arising from the lateral half of the retina of the same side and the nasal half of the retina of the opposite side. These fibres are distributed to three localities:—(1) perhaps the greater portion terminate in the lateral geniculate body; (2) a portion pass over and around the lateral geniculate body and enter the pulvinar; (3) a considerable portion enter the superior quadrigeminal brachium and course in it to terminate in the nucleus of the superior quadrigeminate body. The most evident function of this latter portion is to bear impulses

FIG. 618.—DIAGRAM OF THE PRINCIPAL COMPONENTS OF THE OPTIC APPARATUS. (After Cunningham.)



which, by way of the neurones of the quadrigeminate body, are distributed to the nuclei of the oculomotor, trochlear, and abducent nerves, and thus mediate eye-moving reflexes. The cells of the lateral geniculate body and the pulvinar, about which the retinal fibres terminate, give off axones which terminate in the cortex of the visual area, chiefly the cuneus, of the occipital lobe. In reaching this area they curve upwards and backwards, coursing in a compact band of white substance known as the optic radiation (radiatio occipito-thalamica, fig. 643). Some of the fibres of the optic radiation probably arise also in the superior quadrigeminate body. It also is in large part composed of fibres arising from the cells of the occipital cortex, which pass from the cortex to the pulvinar, superior quadrigeminate bodies, and possibly some to the medulla oblongata and spinal cord.

The *mesial root* of the optic tract contains few, if any, true visual fibres. It runs into the medial geniculate body, and neither it nor this body are appreciably affected after extirpation of both eyes. It may be considered as wholly representing

the fibres of **Gudden's commissure** (inferior cerebral commissure). This commissure consists of fibres which connect the medial geniculate bodies of the two sides with each other, and which, instead of crossing the mid-line through the mesencephalon, course in the optic tracts and cross by way of the posterior portion of the optic chiasma. It consists of fibres which both arise and terminate in each of the bodies, and, therefore, of fibres coursing in both directions.

THE CEREBRAL HEMISPHERES

The cerebral hemispheres in man form by far the largest part of the central nervous system. Together, when viewed from above, they present an ovoid surface, markedly convex upwards, which corresponds to the inner surface of the vault of the cranium. The greatest transverse diameter of this surface lies posteriorly in the vicinity of the parietal eminences of the cranium. The outline of the dorsal aspect varies according to the form of the cranium, being more spheroidal in the brachycephalic and more ellipsoidal in the dolichocephalic forms. The hemispheres are separated from each other dorsally by a deep median slit, the *longitudinal fissure,* into which fits a duplication of the inner layer of the dura mater known as the falx cerebri. The posterior or occipital extremities of the hemispheres overlap the cerebellum, and thus entirely conceal the mesencephalon and thalamencephalon. They are separated from the dorsal surface of the cerebellum and the corpora quadrigemina by the deep *transverse fissure.* This is occupied by the tentorium cerebelli, which is similar to and continuous with the falx cerebri and is connected with the tela chorioidea of the third ventricle below.

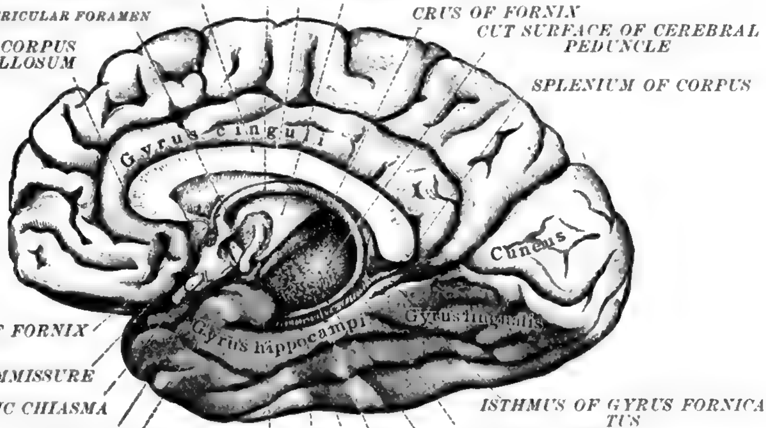
Each of the hemispheres is usually described as having three poles or projecting extremities, and three surfaces bounded by intervening borders. The most anterior projection is the **frontal pole.** This is near the mid-line, and with its fellow of the other hemisphere, forms the frontal end of the ovoid contour of the cerebrum. The **occipital pole** is the most projecting portion of the posterior and inferior end, and is more rounded and thus not so near the mid-line as the frontal pole. The ventrolateral portion of the hemisphere is separated anteriorly by the deep *lateral fissure* (fissure of Sylvius) into a distinct division, the temporal lobe, and the anterior portion of this lobe projects prominently forwards and is known as the **temporal pole.**

The surfaces of the hemisphere are—(1) the dorso-lateral or *convex surface;* (2) the *medial surface;* and (3) the *basal surface.* The convex surface comprises the entire rounded aspect of the hemisphere visible previous to manipulation or dissection, and is the surface subjacent to the vault of the cranium. The mesial surface is perpendicular, flat, and parallel with that of the other hemisphere, the two bounding the longitudinal fissure and for the most part in contact with the falx cerebri. The **superomesial border** intervenes between the convex and medial surfaces, and is thus convex and extends from the frontal to the occipital pole.

The more complex *basal surface* fits into the anterior and middle cranial fossæ, and posteriorly rests upon the tentorium cerebelli. Thus it is subdivided into—(*a*) an *orbital area,* which is slightly concave, since it is adapted to the orbital plate of the frontal bone, and is separated from the convex surface by the necessarily arched **superciliary border** and from the mesial surface by the **internal orbital border,** the latter being straight and extending from the frontal pole mesial to the olfactory bulb and tract; (*b*) a *tentorial area* or surface, which is arched in conformity with the dorsal surface of the cerebellum. This is separated from the convex surface by the **infero-lateral border,** which runs from the occipital to the temporal pole; and from the mesial surface by the **internal occipital border,** which is a more or less rounded ridge extending from the occipital pole obliquely upwards in the angle formed by the junction of the perpendicular falx cerebri and the horizontal tentorium cerebelli. This border is best seen in brains which have been hardened with the membranes *in situ.* The remainder of the basal surface includes the optic portion of the hypothalamus already considered, and the small depressed and punctate area, the anterior perforated substance, which is penetrated by the antero-lateral group of the central branches of the anterior and middle cerebral arteries and into which the striæ of the olfactory trigone disappear. In addition to the orbital area the basal surface of the hemisphere shows signs of the impress of the petrous portion of the temporal bone and of the great wing of the sphenoid.

The corpus callosum.—In their early development as lateral dilations of the anterior primary brain-vesicles, the hemispheres are connected with each other only at the anterior end of the thalamencephalon, where they are both continuous with the lamina terminalis. As development proceeds and the hemispheres extend upwards, backwards, forwards, and laterally to completely conceal the base, and as the pallium thickens and its folds begin to appear, the two hemispheres become united across the mid-line above the thalamencephalon and the third ventricle by the formation of the great cerebral commissure, the **corpus callosum.** After removal of the falx cerebri from the longitudinal fissure, the dorsal surface of the corpus callosum may be exposed by drawing apart the contiguous mesial surfaces of the hemispheres. It consists of a dense mass of pure white substance coursing transversely, and arises as outgrowths from the cortical cells of both hemispheres. Thus it is the great pathway which associates the cortex of the two sides of the telencephalon. Only the smaller medial portion of the body lies free in the floor of the longitudinal fissure, by far the greater part being concealed in the substance of the hemispheres, where its fibres radiate to and from different localities of the pallium, forming the *radiation of the corpus callosum.* Its surface shows numerous transverse markings, the *transverse striæ*, which indicate the

Fig. 619.—Mesial and Tentorial Surfaces of Right Cerebral Hemisphere, Viewed from the Left. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



course of its component bundles of fibres. In addition there may be seen two delicate, variable longitudinal bands running over its surface on each side of the mid-line. The **medial longitudinal stria** runs close to the median plane, around the anterior end into the gyrus subcallosus (fig. 620), and over the posterior end downwards and lateralwards to connect with the hippocampal gyrus of the base of the telencephalon. The **lateral longitudinal stria** is more delicate than the mesial stria, and courses lateralwards, and can only be seen within the sulcus of the corpus callosum (fig. 620).

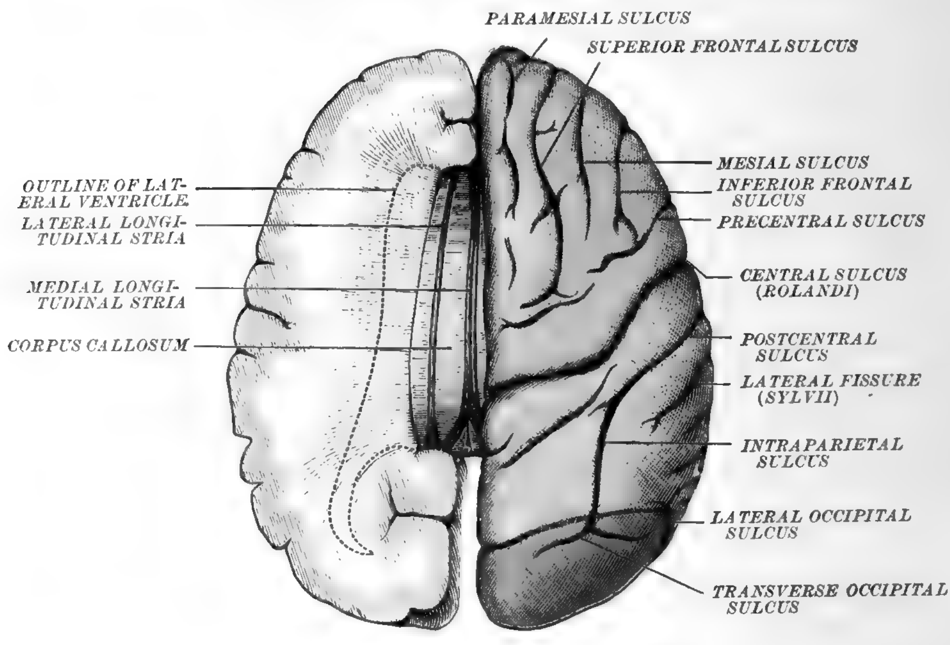
When severed along the median plane, it may be seen that the anterior margin of the corpus callosum is turned abruptly downwards, forming the **genu,** and that this turn continues, so that the tapering edge of the body points posteriorly and constitutes the **rostrum** (figs. 615 and 619). The rostrum is in contact with the lamina terminalis of the third ventricle below by a short, thin, dorso-frontal continuation of this lamina, known as the **rostral lamina.** The rostral lamina may be considered as beginning at the anterior cerebral commissure with the anterior aspect of which it is in contact, and extending to the rostrum. Beginning with the rostrum and genu, the corpus callosum arches backwards as the **body of the corpus callosum,** and ends over the corpora quadrigemina in its rounded, thickened posterior margin, the **splenium.** It is bounded above by the sulcus of the corpus callosum, and, attached to its concave

inferior surface, are the tela chorioidea of the third ventricle, the fornix, the septum pellucidum, and the medial walls of the lateral ventricles.

Each cerebral hemisphere includes—(1) a superficial and much folded mantle or *pallium,* divided into lobes and gyri, and consisting of grey substance, the *cortex,* covering an abundant mass of white substance; (2) a modified portion, the *rhinencephalon,* having especially to do with the impulses brought in by the olfactory nerve; (3) a cavity, the *lateral ventricle;* and (4) a buried mass of grey substance or basal ganglia which together with the *internal capsule* of white substance, is known as the *corpus striatum.*

Gyri, fissures, and sulci.—The cerebral pallium is thrown into numerous and variable folds or *gyri* (convolutions). These are separated from each other by corresponding furrows, the deeper and most constant of which are called *fissures;* the remainder, *sulci.* All the fissures and the main sulci are named. There are, however, numerous small and shallow sulci to which names are seldom given. These occur as short branches of main sulci or as short, isolated furrows bounding small gyri which connect adjacent gyri. These small gyri are likewise seldom given individual

Fig. 620.—Diagram of Convex Surface of Right Cerebral Hemisphere and Part of Upper Surface of Corpus Callosum.



names. They are very variable both in different specimens and in the two hemispheres of the same specimen. Collectively, they are the so-called *gyri transitivi.* Certain groups of them are named according to their locality, such as *orbital gyri* and *lateral occipital gyri.* Even the main gyri (and sulci) are very irregular in detail. Some of the main and deeper fissures are considerably deeper than others. Some are infoldings of the grey cortex, so deep that a portion of their course may be indicated as slight bulgings in the walls of the lateral ventricles, e.g., the hippocampal and collateral fissures. While the general surface pattern is similar for all normal human brains, yet when a detailed comparison is made, the given gyri of different specimens are found to vary greatly. Neither are the main gyri of the two hemispheres of the same brain ever entirely alike.

Origin of the Gyri.—The gyri (and sulci) are the result of processes of unequal growth—folds necessarily resulting from the surface portion of the hemispheres increasing much more rapidly than the central core. In the early periods of fetal life the surfaces of the hemispheres are quite smooth. In many of the smaller mammals this condition is retained throughout life, but in the larger mammals, including man, as development proceeds the cerebral cortex becomes thrown into folds. The absolute amount of the grey substance of the hemispheres varies with

the bulk of the animal, and apparently with its mental capabilities. This is especially true of the cortex, for in the larger brains, and that of man especially, by far the greater amount of the cerebral grey substance lies on the surface. Therefore, in either the growth or evolution of a small animal into a large one the amount of cerebral grey substance is increased, and in this increase the surface area of the brain is necessarily enlarged. It is a geometrical law that in the growth of a body the surface increases with the square, while the volume increases with the cube of the diameter. The cerebral hemisphere is a mass the increase of whose volume does not keep the required pace with the increase of its surface area or cortical layer. The white substance which forms the pallium arises in large measure as outgrowths from the cells of the cortical layer, and thus it can only increase in a certain proportion to the grey substance. Therefore, the surface mantle of grey substance of a hemisphere, enlarged in accordance with an increased bulk of body, is greater than is necessary to cover the surface of the geometrical figure formed by the combined white and grey substance. Consequently, in order to possess the preponderant amount of grey substance, the surface of the hemisphere is of necessity thrown into folds. It follows also that the thinner the cortical layer in proportion to the volume of the hemisphere, the greater and more folded will be the surface area. In accordance with this theory small animals have smooth or relatively smooth hemispheres, and that independently of their position in the animal scale or the amount of their intelligence, while large animals have convoluted brains.

The sulci in general begin to appear with the fifth month of fetal life, the larger of them, the fissures, appearing first and in a more or less regular order. Up to the fifth month the encephalon, due to its rapid growth, closely occupies the cranial capsule. During the fifth month the cranium begins to grow more rapidly than the encephalon, and a space is formed between the cerebrum and the inner surface of the cranium. This space allows further expansion of the pallium, and at the time it is relatively greatest (during the sixth month) the form and direction of the principal gyri and sulci begin to be indicated. As growth proceeds the unrestricted expansion of the pallium results in the gyri again approaching the wall of the cranium, and during the eighth month of fetal life they again come in contact with it. Finally, the later relative growth of the cranium results in the space found between it and the cortex in the adult. It is obvious that the relation of the cranium may be a factor in the causation of the gyri, for the increase of surface area necessitated by the increased amount of cortical grey substance might be limited by a cranial cavity of small size and then the increase of surface could only be obtained by folding. It is probable that the second contact of the cortex with the cranium (during the eighth month) may at least cause a deepening and accentuation of the gyri already begun. Evidently the form of the cranium modifies the gyri, and to a certain extent probably determines their direction, for in long, dolichocephalic crania the antero-posterior gyri are most accentuated, and in the wide, brachycephalic crania the transverse gyri are most marked. At birth all the main fissures and sulci are present, but some of the smaller sulci appear later. In the growing pallium both the bottoms of the sulci as well as the summits of the gyri move away from the geometrical center of the hemisphere, the summits more rapidly, and hence the sulci or fissures first formed grow gradually deeper as long as growth continues.

The mechanical factors in the growth processes which result in the more or less regular arrangement of the gyri of the hemispheres of a given group of animals have not been satisfactorily determined. It has been suggested that the differences in arrangement of the gyri in different groups of animals may be in part dependent upon the functional importance of the various regions—the amount of grey substance varying with the functional importance, and the consequent local increases being accompanied by resultant local foldings. This idea is supported by the fact that while the somæsthetic (sensory-motor) area of the cortex varies with the bulk of the body, the frontal gyri, so much developed in man and which are one of the chief regions of the associational phenomena, are relatively independent of and do not vary with the weight of either the body or the brain.

Surface Area.—The total surface area of the adult human telencephalon is about 2300 sq. cm. Of this area almost exactly one-third is contained on the outer or exposed surfaces of the gyri, while the other two-thirds is found in the walls of the sulci and fissures.

Lobes of the Telencephalon and the Fissures and Sulci

The folded pallium of each hemisphere is arbitrarily divided into lobes, partly by the use of certain of the main fissures and sulci as boundaries and partly by the use of imaginary lines. These divisions are six in number, themselves subdivided into their component gyri:—

(1) Temporal lobe.
(2) Central lobe or Insula (Island of Reil).
(3) Frontal lobe.
(4) Parietal lobe.
(5) Occipital lobe.
(6) Olfactory brain or rhinencephalon (including the structures often grouped under the two names *olfactory lobe* and *limbic lobe*).

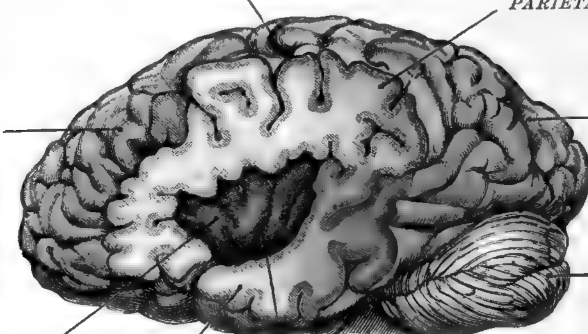
This division of the cortex of the hemisphere is largely a merely topographical one. With the exception of the temporal lobe and the rhinencephalon, it has little of either morphological or functional value. The occipital lobe contains the recognised visual area of the cortex, but this area, as such, does not involve all of the

lobe. In their functional significance, the frontal and parietal lobes, especially, overlap each other.

The temporal lobe.—This is the first lobe whose demarcation is indicated. During the second month of intra-uterine life there appears a slight depression on the lateral aspect of the then smooth hemisphere. As the pallium further grows, this depression deepens into a well-marked fossa with a relatively broad floor. This fossa marks the beginning of the lateral cerebral fissure or fissure of Sylvius, and is, therefore, known as the *Sylvian fossa*. As the pallium continues to project outwards, the folds which form the margins of the Sylvian fossa increase in size and height and begin to overlap and conceal its broad floor. The overlapping folds thus become the **opercula,** and as their lips approach each other, there results the deep fissure of Sylvius, which marks off anteriorly a ventro-lateral limb of the pallium, termed by position the temporal lobe. As growth proceeds further, the temporal lobe thickens, the temporal pole extends further forwards and becomes a free projection, thus lengthening the fissure of Sylvius and resulting in the inferior extension or stem of this fissure, which runs between the temporal pole and the frontal lobe and curves under so as to appear on the basal surface of the hemisphere. Finally the cortex of the lobe itself is thrown into folds or gyri. Its posterior end is never marked off from

Fig. 621.—Diagram of the Convex Surface of the Left Cerebral Hemisphere showing the Five Principal Lobes of the Pallium.

The opercular regions of the frontal, parietal, and temporal lobes are removed to show the central lobe or island of Reil.



the lobes above and behind, except by arbitrary lines which will be mentioned in connection with those lobes.

The temporal lobe forms part of the lateral convex and tentorial surfaces of the hemisphere, and its anterior portion is adapted to the surface of the middle cranial fossa. It thus has a superior and lateral surface and a basal and tentorial surface. In these surfaces are the following gyri with their intervening and bounding sulci:—

The **superior temporal gyrus** is bounded by the posterior ramus of the lateral fissure, and extends from the temporal pole backwards into the supra-marginal region of the parietal lobe above. The upper margin of this gyrus constitutes the **temporal operculum,** in that it aids in overlapping and enclosing the insula in the floor of the lateral fissure. This margin is for the most part smooth, being occasionally interrupted by a few weak twigs of the lateral fissure. It is separated from the gyrus below by the **superior temporal sulcus,** which is parallel with the posterior ramus of the lateral fissure and is frequently called the *parallel sulcus*. The posterior extremity of this sulcus divides the angular gyrus of the parietal lobe, and its anterior end disappears in the temporal pole, sometimes as a continuous groove, sometimes in isolated pieces.

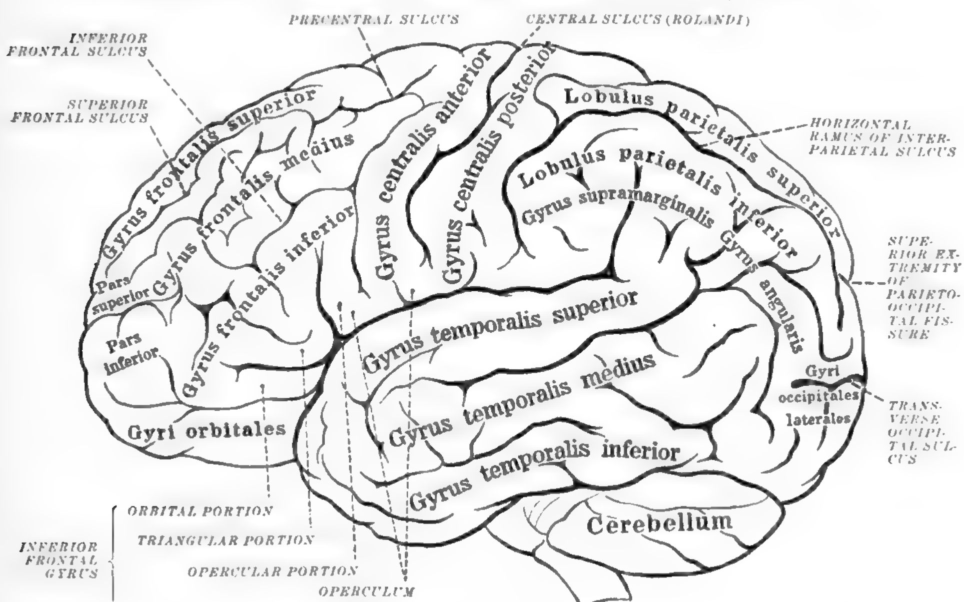
The **middle temporal gyrus** likewise begins in the temporal pole and is continuous backwards into the angular gyrus of the parietal lobe.

The **inferior temporal gyrus** forms the infero-lateral border of the temporal lobe, and is usually more broken up than the two gyri above it. It begins continuous with them in the temporal pole, and extends horizontally backwards into the lateral gyri of the occipital lobe. It is separated from the middle gyrus by the **middle temporal sulcus,** which likewise is never so continuous a furrow as the superior temporal sulcus. Frequently it occurs in detached portions and often terminates within the temporal lobe.

The **fusiform gyrus** is in the basal and tentorial surface of the lobe (fig. 624). Its usual somewhat spindle shape suggests its name, and it is continuous backwards into the occipital gyri, or its posterior end may be completely isolated by a union of the *inferior temporal sulcus* and the **collateral fissure,** which two furrows separate it from its neighbours on either side. Anteriorly the fusiform gyrus runs into the common substance of the other three gyri at the temporal pole.

The **lingual gyrus** is usually included in the tentorial surface of the temporal lobe, though in some texts it is regarded as a part of the occipital lobe. Its larger, posterior portion is continuous with and lies within the boundaries of the occipital lobe.

FIG. 622.—OUTLINE DRAWING OF CONVEX SURFACE OF LEFT CEREBRAL HEMISPHERE. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



Bounded laterally by the collateral fissure, it is continuous anteriorly into the hippocampal gyrus of the rhinencephalon.

All of the sulci give off occasional lateral twigs (*transverse temporal sulci*) which themselves may or may not branch, and which tend to divide the main gyri into **transverse temporal gyri.**

The lateral fissure (fissure of Sylvius).—As promised in its origin by the overlapping and enclosing of the broad floor of the Sylvian fossa by the adjacent folds of the pallium, the lateral fissure is the deepest and most conspicuous fissure of the cerebral hemisphere. Its main divisions are a short stem and three branches. The **stem** lies in the basal surface of the hemisphere, where it begins in a depression in the anterior perforated substance, the *vallecula Sylvii*, and passes forwards and upwards between and separating the temporal pole and the superciliary border of the frontal lobe. It corresponds in direction with the posterior border of the lesser wing of the sphenoid bone, which projects backwards into it, and it contains the middle cerebral artery, the Sylvian vein, and the sinus alæ parvæ. It appears on the upper surface at a point known in cranial topography as the *Sylvian point*, where it divides into its three branches:—

(1) The **posterior ramus** is the linear continuation of the fissure, and runs horizon-

tally backwards and upwards to terminate in the supra-marginal gyrus of the parietal lobe.

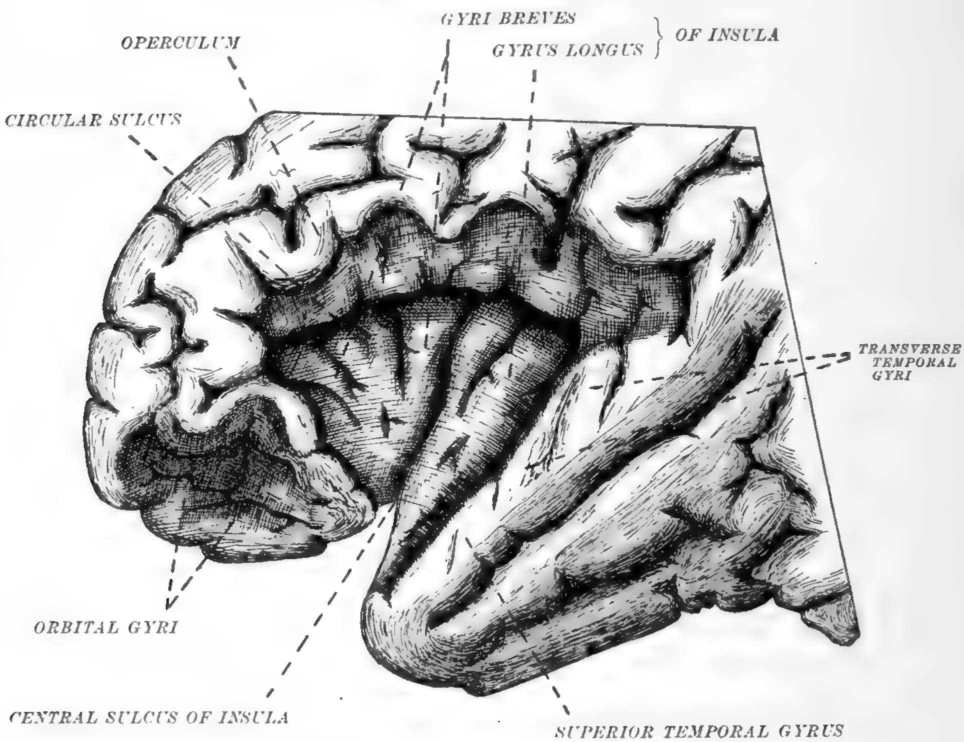
(2) The **anterior ascending ramus** passes upwards for about 10 mm., subdividing the inferior gyrus of the frontal lobe.

(3) The **anterior horizontal ramus** passes forwards from the stem of the fissure about 10 mm., and likewise into the inferior frontal gyrus, but parallel with the superciliary border.

These branches, together with certain smaller collateral twigs, divide the overlapping or opercular portions of the adjacent pallium into (*a*) the *temporal operculum*, which lies below the posterior ramus; (*b*) the fronto-parietal operculum, or *operculum proper*, which lies above and behind the anterior ascending ramus; (*c*) the *frontal operculum*, between the latter and the anterior horizontal ramus; (*d*) and the *orbital operculum*, below the anterior horizontal ramus. Collectively the opercula are known as the *opercula of the insula*.

The central lobe or insula.—The insula or island of Reil is a triangular area of the

Fig. 623.—The Insula with its Gyri and Sulci.



cerebral cortex lying in the floor of the lateral fissure, and concealed by the opercula. Of these, the temporal operculum overlaps the lobe to a greater extent than either the frontal or parietal. More than half of it may, therefore, be exposed by gently pressing away the temporal lobe. The central lobe or island corresponds to the broad floor of the Sylvian fossa of the embryonic brain. In the developed condition its surface is convex lateralwards and is itself folded into gyri. The apex of the triangle appears upon the basal surface of the hemisphere, and is the only portion which may be seen without disturbing the specimen. It appears as the end of a small gyrus under the temporal pole, and in close relation with the anterior perforated substance and the vallecula Sylvii, and is known as the **limen of the insula.** In the folding process by which the opercula accomplish the overlapping and enclosing of the island, there results a deep sulcus which surrounds its entire area except at the limen insulæ. This is known as the **circular sulcus,** or limiting sulcus of Reil. The gyri (and sulci) of the island radiate from the apex of the triangle. The **central sulcus** of the island is the deepest. It runs from below backwards and upwards,

parallel with the central sulcus of Rolando above, and divides the island into a larger anterior and a smaller posterior portion. The anterior portion consists of from three to five short irregular **gyri breves** or precentral gyri, separated by **sulci breves;** the posterior portion consists of a single, slightly furrowed gyrus, which is long and arched and extends from the apex to the base of the triangle. the **gyrus longus.**

The frontal lobe.—This is the most anterior of the lobes of the hemisphere, and like the two lobes behind, it has a convex or outer, a basal, and a mesial surface. The convex surface begins with the frontal pole, and is bounded posteriorly by the *central sulcus* (*Rolandi*); the basal surface extends backwards to the stem of the lateral fissure, covered by the frontal pole; and the mesial surface is separated from the gyrus cinguli of the rhinencephalon (limbic lobe) by the sub-frontal part of the **sulcus cinguli** (calloso-marginal fissure), and from the parietal lobe by a line drawn perpendicularly from the upper extremity of the central sulcus (Rolandi) to the sulcus cinguli. These surfaces include the following gyri and sulci:—

	Gyri.		Sulci.	
Convex surface	Anterior central gyrus.		Precentral sulcus	Superior. Inferior.
	Superior frontal gyrus.		Superior frontal sulcus.	
	Middle frontal gyrus	Superior portion. Inferior portion.	Middle frontal sulcus	
	Inferior frontal gyrus	Opercular portion. Triangular portion. Orbital portion.	Inferior frontal sulcus.	
			Anterior ascending ramus of lateral fissure.	
			Anterior horizontal ramus of lateral fissure.	
Basal surface	Orbital gyri	External. Anterior. Posterior. Internal.	Orbital sulci	External. Internal. Transverse.
	Gyrus rectus.		Olfactory sulcus.	
Mesial surface	Superior frontal gyrus.			
	Marginal gyrus.			
	Paracentral lobule (anterior part).		Rostral sulci.	

Many of the sulci, especially the superior frontal and the rostral sulci, often give off twigs or are broken up into short furrows which give rise to small folds (gyri transitivi), too inconstant to be given special names.

The **anterior central gyrus** (ascending frontal convolution) is the only gyrus of the frontal lobe having a vertical direction. It lies parallel to the central sulcus (Rolandi), and thus extends obliquely across the convex surface from the posterior ramus of the lateral fissure (frontal operculum) to the supero-mesial border, and is continuous on the mesial surface into the anterior portion of the *para-central lobule*. It comprises a large part of the anterior portion of the somæsthetic (sensory-motor) area of the cerebral cortex. It is separated from the horizontal gyri in front by the **precentral sulcus.** This sulcus is developed in three parts, but the upper and middle parts in the fœtal brain usually fuse together, so that in the later condition it consists of a superior and an inferior section. The superior cuts the supero-mesial border of the hemisphere and appears on the mesial surface in the paracentral lobule. On the convex surface it is usually connected with the posterior end of the superior frontal sulcus.

The **superior frontal gyrus** is a relatively broad, uneven convolution, comprising the anterior portion of the supero-mesial border of the hemisphere, and therefore extends horizontally from the precentral sulcus to the frontal pole. It is sometimes imperfectly divided into a superior and an inferior part by a series of detached, irregular furrows, spoken of collectively as the *para-medial sulcus*. The resulting gyri transitivi are of interest in that they are peculiar to the human brain, and are said to be more marked in the higher than in the lower types.

The **middle frontal gyrus** is likewise a broad strip of pallium extending from the precentral sulcus to the frontal pole. It is separated from the superior frontal gyrus by the **superior frontal sulcus,** which is usually continuous into the superior section of the precentral sulcus and thence extends horizontally to the frontal pole. The middle frontal gyrus is in most cases subdivided anteriorly into a *superior* and an *inferior portion* by a **middle frontal sulcus.** This sulcus begins above and runs

into the frontal pole, where, upon reaching the superciliary border, it frequently bifurcates into a transverse furrow, known as the *fronto-marginal sulcus.*

The **inferior frontal gyrus** forms the superior wall of the lateral fissure, and is separated from the middle frontal gyrus by the **inferior frontal sulcus.** This sulcus begins continuous with the inferior section of the precentral sulcus, and extends, very irregularly and frequently interrupted, towards the frontal pole. The gyrus abuts upon the anterior central gyrus, and its posterior portion is divided into three parts (the frontal opercula) by the anterior ascending and horizontal rami of the lateral fissure. The part behind the anterior ascending ramus is the **opercular portion** (a part of the fronto-parietal operculum or operculum proper), sometimes referred to as the *basilar portion.* In most brains this part is traversed by a short oblique furrow, the **diagonal sulcus.** The part between the two anterior rami of the lateral fissure is the cap-shaped **triangular portion.** This portion frequently involves one and sometimes two descending twigs of the inferior frontal sulcus. The part below the anterior horizontal ramus is by position the **orbital portion.**

It is seen that the inferior frontal gyrus gives rise to the whole of the frontal operculum and the anterior half of the fronto-parietal operculum. The opercular portion is of special interest in that in the left hemisphere it constitutes the celebrated convolution of Broca, concerned in the function of speech. The area controlling speech, however, involves the triangular portion as well, and both these parts often appear more developed on the left hemisphere. The development of the opercula of the inferior frontal gyrus is a distinctive characteristic of the human brain. This gyrus does not develop opercula even in the highest varieties of apes. The development of the function of speech in man no doubt influences the development of the frontal opercula.

On the *basal surface* of the frontal lobe is the orbital area and the gyrus rectus. The more pronounced of the **orbital sulci** are often so joined with each other as to form an H-shaped figure standing parallel to the mesial plane, and thus they comprise an *internal*, an *external*, and a *transverse orbital sulcus.* This figure naturally divides the orbital area into four gyri:—(1) The **external orbital gyrus** is the basal continuation of the inferior frontal gyrus, and is thus related to the orbital portion of the frontal operculum; (2) the **anterior orbital gyrus** is continuous at the pole with the middle frontal gyrus; (3) the **posterior orbital gyrus** is closely related to the limen insulæ and the stem of the lateral fissure, and its outer part is in relation with the orbital portion of the operculum; (4) the **internal orbital gyrus** is continuous over the superciliary border with the superior frontal gyrus. It frequently contains one or two short, isolated sulci. Its mesial boundary is the straight **olfactory sulcus,** in which lies the olfactory bulb and tract of the rhinencephalon. This sulcus marks off a narrow straight strip of cortex between it and the mesial border of the lobe known as the **gyrus rectus.** The posterior portion of the gyrus rectus comprises a part of the parolfactory area or Broca's area, which functionally belongs to the rhinencephalon.

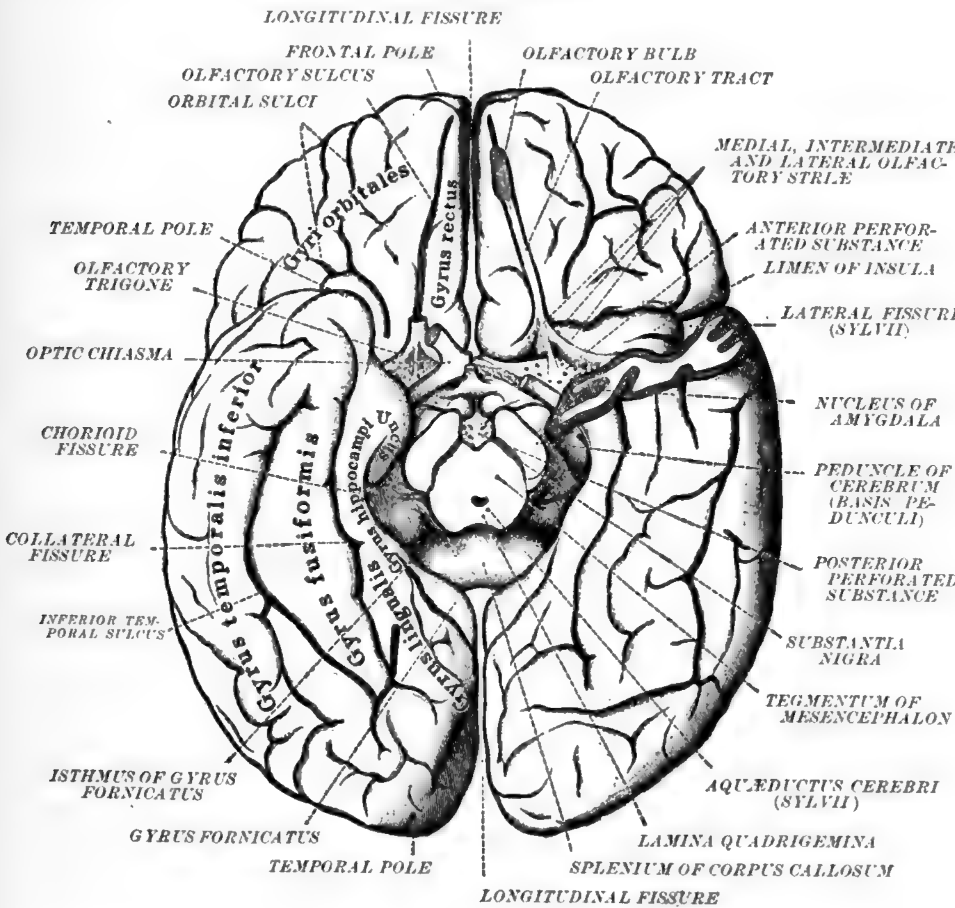
On the *mesial surface* of the frontal lobe the superior frontal gyrus is separated from the gyrus cinguli of the rhinencephalon (limbic lobe) by the well-marked **sulcus cinguli.** Anteriorly the superior frontal gyrus is subdivided by the main stem of the **rostral sulci** into a **marginal gyrus,** and what may be termed a **submarginal gyrus.** The marginal gyrus is usually broken into smaller parts by twigs of the rostral sulci, most of which are perpendicular to the main stem, while the submarginal gyrus is less frequently interrupted. Posteriorly the superior frontal gyrus constitutes the anterior portion of the *paracentral lobule,* a part of the somæsthetic area of the mesial surface of the hemisphere. This lobule is usually marked off anteriorly by a vertical twig from the sulcus cinguli.

The **sulcus cinguli** (calloso-marginal fissure) is the longest and one of the most prominent sulci on the mesial surface of the hemisphere. It divides the anterior portion of the mesial surface into a marginal part above and a callosal part below—in other words, it separates the superior frontal gyrus from the gyrus cinguli. Its **subfrontal portion** begins below the rostrum of the corpus callosum and curves forwards and upwards around the genu, and then turns backwards above the body of the corpus callosum. Before it reaches the level of the splenium, it turns upwards and cuts and terminates in the supero-mesial border of the hemisphere, as the next sulcus behind the upper termination of the central sulcus. This upward turn is the **marginal portion** of the sulcus cinguli. It is sometimes an abrupt curve and sometimes curves gradually, but its marginal relation to the upper end of the central sulcus

is so constant that it serves as a means by which either of the sulci may be identified. The marginal portion separates the paracentral lobule from the precuneus (quadrate lobule), and is wholly within the parietal lobe. One of the most constant twigs of the sulcus cinguli is that which marks off the paracentral lobule from the superior frontal gyrus. Another sometimes divides the paracentral lobule into its frontal and parietal portions. The sulcus cinguli is developed from two and sometimes three (anterior, middle, and posterior) separate furrows, which later extend and fuse into continuity. This method of its development may explain the irregularities frequently met with and the fact that sometimes in the adult the sulcus occurs in separate pieces.

The **central sulcus** (fissure of Rolando) is one of the principal landmarks of the convex surface of the hemisphere. It separates the frontal from the parietal lobe,

Fig. 624.—Basal Surface of the Cerebral Hemispheres. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



and likewise divides the somæsthetic area of the pallium. Its upper end terminates in and usually cuts the supero-mesial border of the hemisphere immediately in front of the termination of the marginal portion of the sulcus cinguli. Thence it pursues an oblique though sinuous course forwards across the convex surface of the hemisphere, forming on the average an angle of about 72° with the supero-mesial border (**Rolandic angle**), and terminates in the fronto-parietal operculum immediately above the posterior ramus, and about 2·5 cm. behind the point of origin of the anterior rami of the lateral fissure. It rarely cuts through the fronto-parietal operculum. In its sinuous course, two bends are most marked:—(1) The **superior genu** occurs at about the junction of the upper and middle thirds of the sulcus and is concave forwards. It accommodates the greater part of that portion of the cortex

which is the motor area for the muscles of the arm, and the development of this area in man probably aids in producing it. (2) The **inferior genu** occurs below, is concave backwards, and is probably in part a result of the superior genu—the turn of the sulcus in resuming its general course. The upper part of this genu also accommodates a smaller (inferior) portion of the arm area.

The **central sulcus** (**Rolandi**) appears in the pallium of the fœtus during the latter part of the fifth month. It then consists of a lower longer and an upper shorter part. Usually these two parts become continuous before birth; very rarely do they remain separate in the adult. The point of their fusion is sometimes manifest within the depth of the sulcus. If the lips of the sulcus be pressed widely apart at about the region of the junction of its middle and upper third, it will be found that the opposing walls give off a number of protuberances or lateral gyri, which dovetail into each other when the sulcus is closed. Sometimes two of these lateral gyri appear fused across the floor of the sulcus, so as to form a bridge of grey substance known as the **deep annectant gyrus.** This interruption of the continuity of the sulcus, when present, represents the point at which the two parts of the sulcus in the fœtal brain joined each other without the continuity becoming wholly completed in the adult. The genua of the adult sulcus may often be due to the precedent parts not being in line at the time of their fusion.

The parietal lobe.—The parietal lobe occupies a somewhat smaller area of the human telencephalon than either the frontal or the temporal lobe. It has a convex and a mesial surface, but no basal surface. It is separated from the frontal lobe in front by the central sulcus; from the occipital lobe behind by the *parieto-occipital fissure* (fig. 626), and by an arbitrary line drawn transversely around the convex surface of the hemisphere from the superior extremity of this fissure to the infero-lateral border; and from the temporal lobe below by the horizontal part of the posterior ramus of the lateral fissure, and by a line drawn in continuity with this horizontal part to intersect the transverse line drawn to limit it from the occipital lobe.

The preoccipital notch.—*In situ,* the infero-lateral border of the posterior portion of the hemisphere rests over a small portion of the parieto-mastoid suture of the cranium, and upon this structure occurs a fold or vertical thickening of the dura mater, which slightly indents the infero-lateral border. This indentation occurs about 4 cm. from the occipital pole, and is considered one of the points of limitation of the parietal from the occipital lobe, and is therefore called the preoccipital notch. While during late fœtal life and early childhood it is well marked, it is usually very slight in the adult brain, and is, as a rule, evident only in brains hardened *in situ.* When it is visible, the arbitrary transverse line from the superior extremity of the parieto-occipital fissure, used as a boundary between the convex surfaces of the parietal and occipital lobes, should be so drawn as to bisect the preoccipital notch.

The *convex surface* of the parietal lobe comprises the following gyri and sulci:—

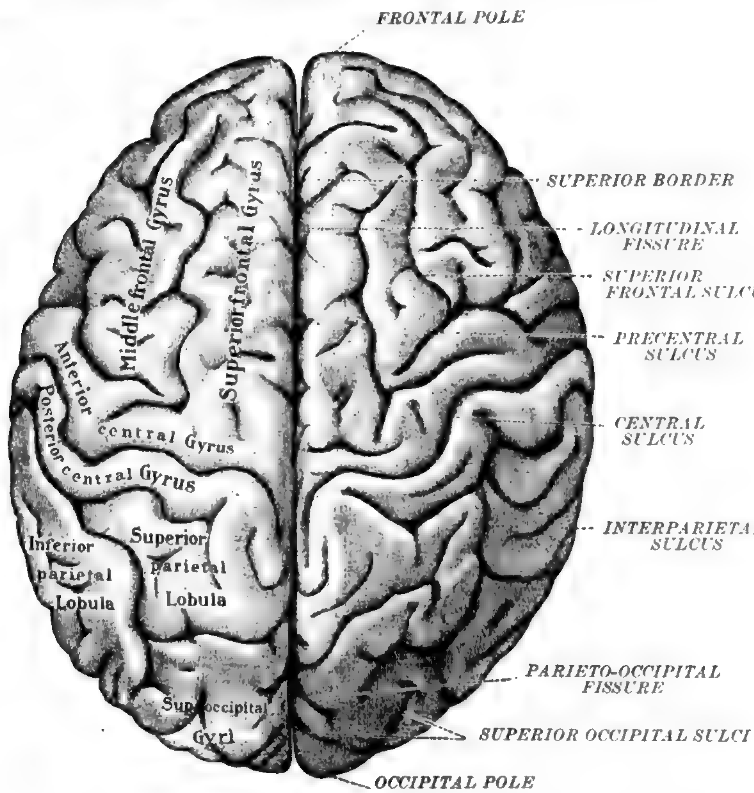
The **posterior central gyrus** (ascending parietal) extends obliquely across the hemisphere parallel with the anterior central gyrus of the frontal lobe, from which it is separated by the central sulcus. Its inferior end is bounded by the posterior ramus of the lateral fissure, and constitutes the posterior or parietal portion of the fronto-parietal operculum. Its upper end takes part in the supero-mesial border of the hemisphere, and is bounded posteriorly by the tip end of the marginal portion of the sulcus cinguli. Its postero-lateral boundary consists of the two more or less vertical rami or factors of the interparietal sulcus, viz., the inferior and superior portions of the *postcentral sulcus,* either continuous with each other or detached.

The **interparietal sulcus** (intraparietal) is often the most complicated sulcus of the pallium. Its development usually begins as four different furrows in the fœtal brain, and the difficulty with which it is traced in the adult brain depends upon the extent to which these four factors become continuous in the later development. When continuity of the furrows is well established, the entire sulcus may be described as consisting of a convex *horizontal ramus,* which gives off a few short collateral twigs and whose either end is in the form of an irregular, reclining ⊣. The transverse bar of the anterior end arises from two of the four factors of the entire sulcus:—(1) an inferior furrow, the *inferior postcentral sulcus,* commencing above the posterior ramus of the lateral fissure and ascending as the boundary of the lower half of the posterior central gyrus, and (2) a superior furrow, the *superior postcentral sulcus,* lying behind the upper portion of the posterior central gyrus, and which, upon approaching the supero-mesial border, may turn backward a short distance parallel with the horizontal ramus, as in fig. 622. When confluent, these two factors form together a continuous **postcentral sulcus.** In the adult the inferior of the two is always continuous with the horizontal ramus; when confluent, the two figures join so as to form the transverse bar of the anterior end of this ramus. The horizontal ramus, which

represents the third of the primary furrows, is continued backwards past the superior extremity of the parieto-occipital fissure into the occipital lobe, where it usually joins the *occipital ramus*, the fourth of the primary furrows. This ramus divides shortly into two branches which run at right angles to the stem, forming the *transverse occipital sulcus*, and thus arises the transverse bar of the posterior end of the interparietal sulcus. The occipital ramus may, however, consist of little more than the transverse bar, which may or may not be joined by the horizontal ramus. The occipital ramus is more frequently separate from the horizontal than is the postcentral sulcus. In their development the inferior postcentral sulcus appears first (during the latter part of the sixth month), the occipital ramus second, the horizontal ramus third, and last, the superior postcentral sulcus.

The **superior parietal lobule** (*gyrus*) is the area of the supero-mesial border of the parietal lobe. It is limited in front by the superior postcentral sulcus, below by the horizontal ramus of the interparietal sulcus, and posteriorly it is continuous

FIG. 625.—CONVEX SURFACE OF THE CEREBRAL HEMISPHERES AS VIEWED FROM ABOVE. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



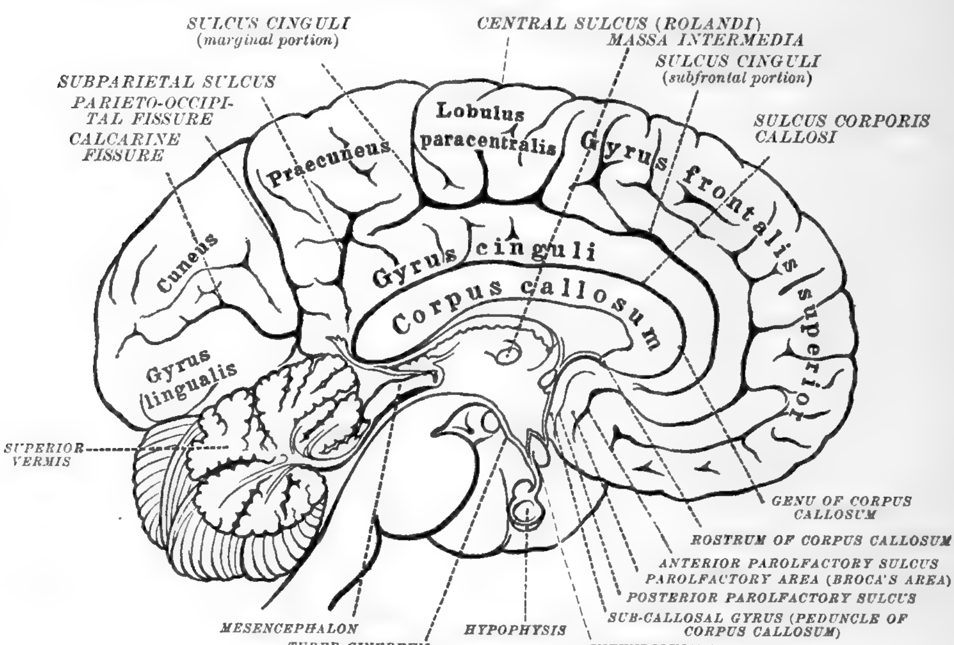
around the superior end of the parieto-occipital fissure into the cortex of the occipital lobe. It is a relatively wide area (lobule), always invaded by collateral twigs of its limiting sulci, and usually contains a few short, isolated furrows. When the parieto-occipital fissure is considerably prolonged over the supero-mesial border (*external parieto-occipital fissure*), the continuation of the lobule about the end of this fissure presents the appearance described as the **parieto-occipital arch.**

The **inferior parietal lobule** is limited in front by the inferior postcentral sulcus, and above by the horizontal ramus of the interparietal sulcus. It is continuous with the cortex of the temporal lobe below, and with that of the occipital lobe behind, and is therefore invaded by the ends of the sulci belonging to these lobes. Its anterior portion is separated from the temporal lobe by the horizontal portion of the posterior ramus of the lateral fissure. The upturned end of this ramus invades the anterior portion of the lobule and the broad fold, arched around this end and continuous behind it into the superior temporal gyrus, is known as the **supramarginal gyrus.**

The **angular gyrus** is the portion which embraces the posterior end of the superior temporal sulcus, and is continuous behind this into the middle temporal gyrus and in front with the superior temporal gyrus. Its shape is usually such as to suggest its name. The most posterior part of the inferior parietal lobule, when arching in a similar way about the end of the middle temporal sulcus and continuous with the temporal gyri on its either side, is known as the **post-parietal gyrus.** This is a smaller area than either of the other two, and, owing to the variability of the end of the middle temporal sulcus, is not always evident.

The *mesial surface* of the parietal lobe is divided into two parts by the marginal portion of the sulcus cinguli. The anterior and smaller part is the mesial continuation of the posterior central gyrus, and comprises the posterior portion of the **paracentral lobule.** It is limited from the part of this lobule belonging to the frontal lobe by a vertical line drawn from the marginal extremity of the central sulcus. The **præcuneus** (*quadrate lobule*) is the posterior and larger part of the mesial surface of the parietal lobe. It is separated from the cuneus of the occipital lobe by the parieto-occipital fissure, and is imperfectly separated from the gyrus cinguli (limbic lobe)

FIG. 626.—OUTLINE DRAWING OF MESIAL SURFACE OF LEFT CEREBRAL HEMISPHERE. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



below by the *subparietal sulcus* (postlimbic fissure), branches of which invade it extensively.

The occipital lobe.—This is a relatively small, trifacial, pyramidal segment, comprising the posterior extremity of the hemisphere, its apex being the occipital pole. Though one of the natural divisions of the cerebral hemisphere, it is very indefinitely marked off from the lobes anterior to it. Though it contains the cortical area of the visual apparatus, only in the brains of man and the apes does it occur as a well-defined projection. In most of the mammalia it is not differentiated at all. Its three surfaces comprise a convex, a mesial, and a tentorial surface.

Its *convex surface* is separated from that of the parietal and temporal lobes by the superior and external extremity of the parieto-occipital fissure, and by an arbitrary line drawn transversely from this extremity to the infero-lateral border of the hemisphere, or so drawn as to bisect the pre-occipital notch when this is evident. The sulci which occur on the convex surface may be described as two, though both of these are very variable in their extent and shape, and their branches are inconstant both as to number and length. (1) The **transverse occipital sulcus** is the most

constant in shape. It extends a variable distance transversely across the superior portion of the lobe, and, as noted above, it is frequently continuous with the interparietal sulcus through its occipital ramus, and when so, it appears as the posterior terminal bifurcation of this sulcus (fig. 624). When detached, it often occurs merely as a definite furrow with few rami, and sometimes the ramus by which it otherwise would join the interparietal sulcus is entirely absent. (2) The **lateral occipital sulcus** is always short, and has its deepest portion below the transverse sulcus. It usually has a somewhat oblique course towards the supero-mesial border. Sometimes it occurs in several detached pieces, then known collectively as the *lateral occipital sulci.*

Therefore, the gyri of the convex surface of the lobe are also variable. They are not sufficiently constant to merit individual names. The lateral occipital sulcus or sulci roughly divide them into an inferior and lateral area, known as the **lateral occipital gyri,** and into a superior area, the **superior occipital gyri.** The lateral area is continuous into the gyri of the temporal lobe, while the superior area is continuous into the gyri of the parietal lobe.

The *mesial surface* of the occipital lobe is separated from that of the parietal lobe (precuneus) and from the gyrus cinguli of the limbic lobe by the well-marked parieto-occipital fissure. It comprises the constantly defined, wedge-shaped lobule known as the **cuneus,** and the posterior and mesial extremity of the **lingual gyrus.** Since the greater portion of the length of the lingual gyrus is involved in the basal surface of the temporal lobe, this gyrus as a whole has been considered as belonging to the temporal lobe (see figs. 619 and 624). The cuneus is separated from the lingual gyrus by the posterior portion of the **calcarine fissure,** which always terminates in a bifurcation, one limb of which invades the cuneus near the superomesial border. In addition the cuneus may contain other twigs from both the fissures bounding it, and also, when wide, may contain one or more short, detached **sulci cunei.**

The **calcarine fissure** and the **parieto-occipital fissure** are almost invariably joined in the human brain, forming a Y-shaped figure, the prongs of which give the cuneus its shape. The calcarine fissure begins on the tentorial surface in the posterior portion of the hippocampal gyrus of the limbic lobe, below the splenium of the corpus callosum, and extends backwards across the internal occipital border of the hemisphere. It then bends downwards and proceeds to its terminal bifurcation in the polar portion of the occipital lobe. The stem or hippocampal portion of the fissure is deeper than the posterior or occipital portion. It produces a well-marked eminence in the inner wall of the posterior cornu of the lateral ventricle, known as the *calcar avis* or *hippocampus minor.* It is developed separately from the posterior portion, which also first appears as two grooves. All three parts are usually continuous with each other before birth.

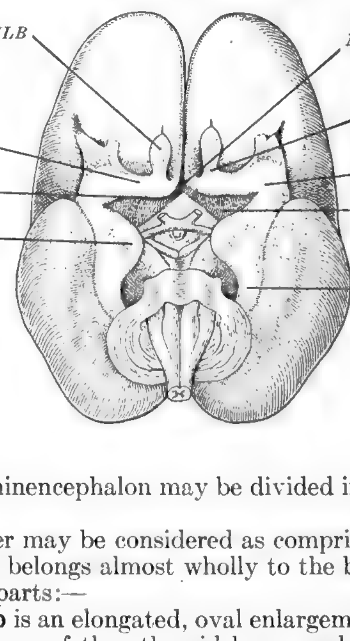
The parieto-occipital fissure usually appears from the first as a continuous groove. It begins in the supero-mesial border of the hemisphere, rarely extending into the convex surface more than 10 mm. (*external parieto-occipital fissure*), thence it extends vertically downwards across the mesial surface (*internal parieto-occipital fissure*), and terminates by joining the calcarine fissure at the region of the downward bend of the latter, or at about the junction of its anterior and middle thirds. In certain of the lower apes and in the brain of the chimpanzee there is no junction between the two fissures, they being kept apart by a narrow neck of cortex, the **gyrus cunei.** Neither are they joined in the human fœtus. If in the adult human brain the region of their junction be opened widely, there will be found a submerged *gyrus transitivus* (deep annectant gyrus), which is the gyrus cunei, superficial in the fœtus. In the higher apes and in microcephalic idiots this gyrus may be on the surface or partially submerged. Two other gyri transitivi (annectant gyri) are to be found by pressing open the calcarine fissure, and they mark the points at which its three original grooves became continuous during its development into a boundary between the cuneus and the lingual gyrus. Of these, the **anterior cuneo-lingual gyrus** crosses the floor of the calcarine fissure on the posterior side of its junction with the parieto-occipital fissure, and therefore near the gyrus cunei. The **posterior cuneo-lingual gyrus** occurs near the region of the terminal bifurcation of the fissure.

The *tentorial surface* of the occipital lobe is blended intimately with that of the temporal lobe, from which it is separated only by an arbitrary line drawn to join the line of demarcation for the convex surface, at the region of the pre-occipital notch, and thence to the isthmus of the gyrus fornicatus—the narrow neck of cortex connecting the gyrus cinguli with the hippocampal gyrus, just below the splenium of the corpus callosum (see fig. 619). The gyri blending the occipital and temporal lobes across this line are the *lingual gyrus,* already mentioned, and the **fusiform gyrus** (occipito-temporal convolution). In fact, the tentorial surface of the lobe may be considered as nothing more than the posterior extremity of the fusiform gyrus, and the inferior portion of the same extremity of the lingual gyrus. The former is often somewhat broken up and is then continuous into the lateral occipital gyri. The two gyri are separated by the *collateral* fissure, the end of which extends into the

lobe. The fusiform gyrus is bounded laterally by the inferior temporal sulcus, which sometimes is continuous by a lateral twig across the posterior end of this gyrus with the collateral fissure.

The rhinencephalon.—The rhinencephalon or *olfactory brain* includes those portions of the cerebral hemisphere which are chiefly concerned as the central connections of the olfactory apparatus. Owing to the preponderant development of the other divisions of the hemisphere, the parts comprising this division appear relatively but feebly developed in the human brain. In most of the mammals the sense of smell is relatively much more highly developed, and in many of the larger mammals the parts comprising the rhinencephalon are of greater absolute size than in man, though their cerebral hemispheres may be considerably smaller. In the human fœtus the parts of the rhinencephalon are relatively much more prominent than after the completed differentiations into the adult condition. In the broader sense of the term the rhinencephalon includes those parts of the hemisphere usually classed as comprising two lobes, viz., the **olfactory lobe** and the **limbic lobe.** Neither of these is a 'lobe' in the sense of comprising a definite segment of the hemisphere, as do the other lobes, and therefore the rhinencephalon cannot be called a distinct lobe. It is so strung out that by one or the other of its parts it is either in contact or continuity with each of the other lobes of the hemisphere.

Fig. 627.—Brain of Human Fœtus of 22·5 Cm. (Beginning of Fifth Month), showing the Parts of the Developing Rhinencephalon Apparent on the Basal Surface. (After Retzius.)



Morphologically, the rhinencephalon may be divided into an **anterior** and a **posterior portion.**

The *olfactory lobe* proper may be considered as comprising the anterior portion of the rhinencephalon. This belongs almost wholly to the base of the encephalon, and consists of the following parts:—

(1) The **olfactory bulb** is an elongated, oval enlargement of grey substance which lies upon the lamina cribrosa of the ethmoid bone, and, practically free, it presses under the anterior end of the olfactory sulcus of the basal surface of the frontal lobe. The numerous thin filaments of the *olfactory nerve* enter the cranium through the foramina of the lamina cribrosa and pass into the ventral surface of the bulb.

(2) The **olfactory tract** is a triangular band of white substance which arises in the olfactory bulb, and continues backwards about 20 mm. to the region of the anterior perforated substance. It appears triangular in transverse section from the fact that its upper side fits into the olfactory sulcus. It becomes somewhat broader at its posterior end.

(3) The **olfactory trigone** is the small triangular ridge joining in front the anterior perforated substance. Upon it the olfactory tract breaks up into three roots, the *lateral, intermediate,* and *medial olfactory striæ.* The lateral olfactory stria emphasizes the lateral portion of the trigone into what is sometimes called the **lateral olfactory gyrus,** a portion of which is directly continuous into the *limen insulæ* (figs. 624 and 627). While a few of the fibres of the lateral stria penetrate this portion,

the greater mass of them pass obliquely outwards over it and gradually disappear in the antero-lateral portion of the anterior perforated substance, in which some of them terminate, but through which most of them pass to curve into the anterior end of the hippocampal gyrus and terminate there, chiefly in the uncus. In most of the mammals the lateral stria is so strong that it appears as a superficial white band passing directly into the uncus.

(4) The **parolfactory area** (Broca's area) involves the mesial extension of the olfactory trigone, and is concerned with the *medial olfactory* stria. On the basal surface of the hemisphere this area involves the posterior extremity of the gyrus rectus—a portion of which is sometimes separated from the remainder of the gyrus by a ventral prolongation of the *anterior parolfactory sulcus* of the medial surface (see figs. 626 and 624). This prolongation when present has been called the **fissura serotina.** On the medial surface the parolfactory area appears as a definite gyrus bearing its name. In front this is separated from the superior frontal gyrus by the anterior parolfactory sulcus, and from the subcallosal gyrus behind by the deeper *posterior parolfactory sulcus* (fig. 626). It is continuous above into the gyrus cinguli of the limbic lobe, the posterior part of the rhinencephalon. A large portion of the fibres of the medial stria are lost in the parolfactory area, and are known to terminate about the cells there. This stria or root of the olfactory tract forms a slight ridge on the ventral surface of the area, which is frequently prominent enough to retain the name **medial olfactory gyrus** applied to it in the fœtal brain (fig. 627).

(5) The **subcallosal gyrus** (peduncle of the corpus callosum) is the narrow fold of the pallium which lies between the posterior parolfactory sulcus and the rostral lamina and the ventral continuation of the latter into the lamina terminalis. It begins above, in part fused to the rostrum of the corpus callosum, and in part continuous with the gyrus cinguli, and below it goes over into the anterior perforated substance. Some fibres of the medial olfactory stria disappear in the substance of this gyrus.

(6) The **anterior perforated substance** must be considered with the rhinencephalon, but, like the limen insulæ, it can only be considered as belonging in part to this division of the brain. It comprises the basal region between the optic chiasma and tract and the olfactory trigone. Usually the posterior parolfactory sulcus (*fissura prima* of the embryo) is sufficiently evident to more or less distinctly separate it from the latter. A few fibres from the middle stria are known to disappear within its depths, and, as mentioned above, many fibres from the lateral stria also pass into it. The intermediate *olfactory stria* is always much the weakest of the three striæ, and in many specimens is apparently absent. The fibres of this stria run almost straight backwards and plunge directly into the anterior perforated substance, where some of them are known to terminate, while others continue into the uncus. On embryological grounds, the subcallosal gyrus and the anterior perforated substance are classed as the posterior division of the 'olfactory lobe' or anterior part of the rhinencephalon.

The olfactory bulb and tract arise as a hollow outgrowth from the lower and anterior part of the anterior of the three primary vesicles. It is a tubular structure at first, and in many of the mammals the cavity maintains throughout life as the *olfactory ventricle*. In man the cavity becomes occluded and the ependyma and gelatinous substance which surround it become the grey core of the bulb and tract of the adult.

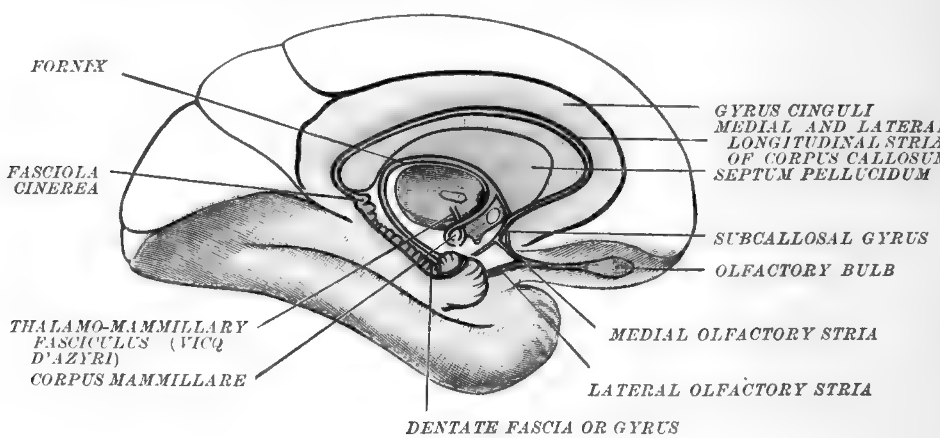
The grey substance persists and developes chiefly in the bulb, and in fact produces it as such. It is much thicker on the ventral surface of the bulb than on the dorsal surface, and in section shows definite layers. From within outwards, the principal of these layers are—(1) the layer of large cells whose shape suggests their name, *mitral cells;* (2) large dendrites of the mitral cells project towards the surface and there break up into numerous telodendria which copiously interdigitate with like telodendria of the entering fibres of the olfactory nerve, thus forming rounded, much tangled glomeruli and the layer containing these, the *glomerular layer;* (3) the superficial layer, or *olfactory layer*, consists of the fibres of the olfactory nerve which form a dense interlacement with each other on the ventral surface of the bulb before they pass into its interior. The dorsal surface of the bulb becomes formed almost wholly of the fibres which arise as axones of the mitral cells and pass backwards to form the olfactory tract, and thence to their localities of termination, chiefly by way of the three striæ. Along the dorsal aspect of the olfactory tract the gelatinous substance of the core may show through as a grey ridge.

The so-called **limbic lobe** (a name introduced by Broca in 1878) consists of the structures which may be considered as comprising the **posterior portion of the rhinencephalon.** It takes part in both the medial and tentorial surfaces of the hemisphere. Seen from the medial surface, it forms an irregular elliptical figure

which encloses the corpus callosum and the extremities of which approach each other at the anterior perforated substance, where they are continuous with the structures of the anterior portion of the rhinencephalon. The figure is bounded externally by the sulcus cinguli above, by the subparietal sulcus (postlimbic sulcus) and the anterior limb of the calcarine fissure behind, and by the collateral fissure below. These respectively separate it from the frontal, parietal, occipital, and temporal lobes. It comprises the following structures which are either wholly or in part devoted to the functions of the olfactory apparatus:—

1. Gyrus fornicatus
   - Gyrus cinguli (cingulum).
   - Isthmus of the gyrus fornicatus.
   - Hippocampus
     - hippocampal gyrus.
     - uncus.
     - dentate fascia.
     - fimbria.
2. The medial and lateral longitudinal striæ upon the corpus callosum.
3. The fornix.
4. The corpus mammillare and thalamo-mammillary fasciculus to the anterior nucleus of the thalamus.
5. Part of anterior cerebral commissure.
6. Part of septum pellucidum.

Fig. 628.—Diagram showing Position of Structures Comprising the Limbic Lobe as Seen from the Mesial Aspect of the Cerebral Hemisphere.



The **gyrus fornicatus** comprises the greater mass of the limbic lobe. As seen above, it is a term used to collectively represent a number of conjoined structures. Being an incomplete ellipse in form, its two ends are united to form a closed ring by means of the connection of the parolfactory area with the gyrus cinguli and the connection of the anterior perforated substance with the uncus of the hippocampal gyrus. It is best described in terms of its component parts.

The **gyrus cinguli** begins in junction with the area parolfactoria below the anterior end of the corpus callosum, and curves above so as to entirely embrace the upper surface of the latter. It is separated from the frontal lobe by the sulcus cinguli (calloso-marginal fissure), from the parietal lobe by the subparietal sulcus, and from the corpus callosum below by the **sulcus of the corpus callosum.** By the latter it is separated from the longitudinal striæ of the upper surface of the corpus callosum. The gyrus cinguli covers over, and its cells are closely associated with, the **cingulum,** a well-marked band of white substance, which follows the gyrus backwards to turn around the splenium of the corpus callosum, and then course forwards into the hippocampal gyrus to the uncus. The cingulum is largely recruited from the medial olfactory stria and from fibres arising in the parolfactory area and the anterior perforated substance.

The **isthmus of the gyrus fornicatus** is the constricted portion connecting the posterior end of the gyrus cinguli with that of the hippocampal gyrus (fig. 619). It is

bounded externally by the anterior end of the calcarine fissure, and is associated with the forward turn of the cingulum.

The **hippocampus** is the name applied to the curved appearances produced in the floor of the lateral ventricle by the peculiar foldings of this part of the cerebral cortex. The *hippocampal gyrus* is the main gyrus of the tentorial surface of the limbic lobe. Externally it is separated from the fusiform gyrus by the collateral fissure, and it is bounded internally by the **hippocampal** or **dentate fissure.** Posteriorly it is partially divided by the calcarine fissure into the lingual gyrus (of the temporal lobe) and the isthmus of the gyrus fornicatus. Its anterior extremity is hooked backwards and is known as the **uncus.** This is almost entirely separated from the temporal lobe by a groove, the **temporal notch.** If the hippocampal fissure be opened up, the **dentate fascia** or gyrus and the *fimbria* will be seen. These lie side by side, separated by the shallow **fimbrio-dentate sulcus.** The free edge of the dentate gyrus presents a peculiarly notched appearance, produced by numerous parallel grooves cutting it transversely. Its posterior end, sometimes called the *fasciola cinerea*, continues backwards over the splenium of the corpus callosum, and upon the upper surface of the corpus callosum appears as a thin strip of grey substance which contains embedded in it the *medial* and *lateral longitudinal striæ.* This thin strip is sometimes called the **supracallosal gyrus,** and is thought to represent a vestigial part of the hippocampal gyrus. The **fimbria** is but the fimbriated, free border of the posterior or end of origin of the fornix, so folded as to project into the hippocampal fissure, parallel with the dentate fascia. It is a conspicuous band composed almost entirely of white substance, continuous laterally with the thick stratum covering the ventricular surface of the hippocampus. It begins anteriorly in the hook or recurved extremity of the uncus. Traced backwards, it is seen to curve upwards, and within the ventricle it becomes part of the general accumulation of the white substance (*alveus*) of the surface of the hippocampus, which accumulation is the beginning of the fornix. The free border of the fimbria (seen in section) is known as the *tænia fimbriæ.* The fimbria is separated from the cerebral peduncles by the **chorioid fissure,** the thin, non-nervous floor of which alone intervenes between the exterior of the brain and the cavity of the lateral ventricle.

The hippocampal fissure attains its greatest depth between the dentate fascia and the hippocampal gyrus, and the resulting eminence produced in the floor of the lateral ventricle is known as the **hippocampus major,** as distinguished from the lesser eminence produced posteriorly by the end of the calcarine fissure and known as the *hippocampus minor* (calcar avis). The collateral fissure may likewise produce a bulging in the wall of the ventricle, the *collateral eminence.* In transverse sections of the hippocampus major, the layers of grey and white substance present a coiled appearance known as the **cornu ammonis.** Externally the medial surface of the hippocampal gyrus adjoining the dentate fascia has reflected over it a delicate reticular layer of white substance known as the *substantia reticularis alba* (*Arnoldi*).

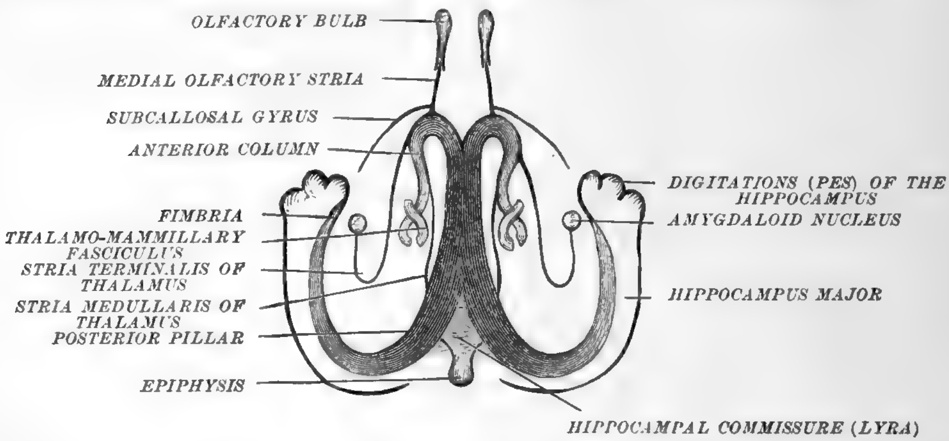
The fornix is the great association pathway of the limbic lobe, and is largely concerned in the apparatus of the rhinencephalon. It is a bilateral structure arched beneath the corpus callosum, with which it is connected anteriorly by the septum pellucidum. Posteriorly it passes in contact with the splenium. It consists of two prominent strips of white substance, one for each hemisphere, the ends of which are separate from each other, while their intermediate parts are fused across the mid-line. These run above the tela chorioidea of the third ventricle, and their lateral edges (*tæniæ fornicis*) rest, on each side, along the line of the tænia chorioidea. The posterior, separate ends are known as the posterior pillars or crura of the fornix; the fused, intermediate portion is the body, and the separate, anterior ends are the anterior pillars or columns of the fornix.

The posterior pillars or crura of the fornix.—When seen from the medial aspect of the hemisphere, the fused portion of the fornix, in the separation of the hemispheres, is split along the mid-line (fig. 619). The half under examination may be seen to course obliquely outwards under the splenium of the corpus callosum, and then, continuous with the fimbria, to curve forwards and downwards towards the uncus. The greater mass of the fibres coursing in the fornix arise as outgrowths of the cells of the uncus, hippocampal gyrus, and dentate fascia. They accumulate as a dense stratum on the ventricular surface of these gyri, termed the **alveus,** which crops outwards as the fimbria and which passes backwards and upwards; upon reaching the region of the splenium it turns obliquely forwards under it and approaches the

mid-line, to fuse with the like bundle from the hippocampal gyri of the opposite side. The bundles thus arising from the two sides are the posterior pillars or crura of the fornix. They appear as two flattened bands of white substance which come in close contact with and even adhere to the splenium.

The angle formed by the mutual approach of the posterior pillars of the fornix is crossed by a lamina of commissural fibres connecting the hippocampal gyri of the two hemispheres (fig. 631). This lamina is the **hippocampal commissure** (psalterium or lyra), and being of a different functional direction, should not be considered a

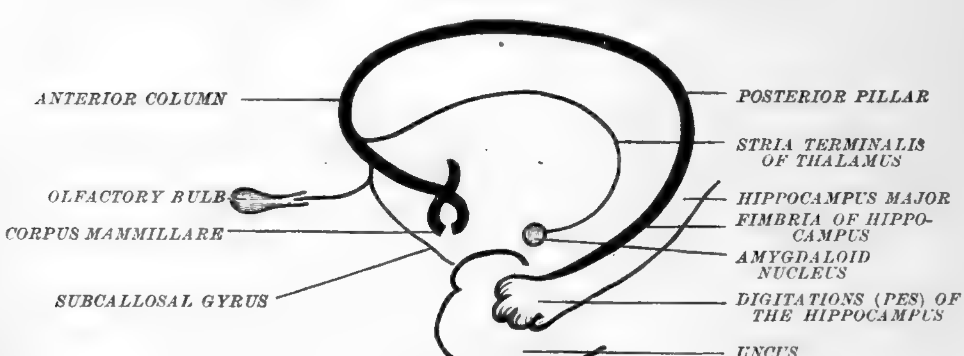
FIG. 629.—DIAGRAM SHOWING FORNIX AND ITS CONNECTIONS AS SEEN FROM ABOVE.



part of the fornix. Usually the hippocampal commissure and the posterior crura are in close contact with the under surface of the splenium. When occasionally they do not adhere, the space between is known as **Verga's ventricle.**

The body of the fornix appears as a triangular plate of white substance produced by the fusion of the pillars. Its base or widest portion is behind. It is not always bilaterally symmetrical. Its upper surface is attached by the septum pellucidum to the under surface of the corpus callosum. Below, it lies over the tela chorioidea of the third ventricle, which separates it mesially from the cavity of the third ventricle

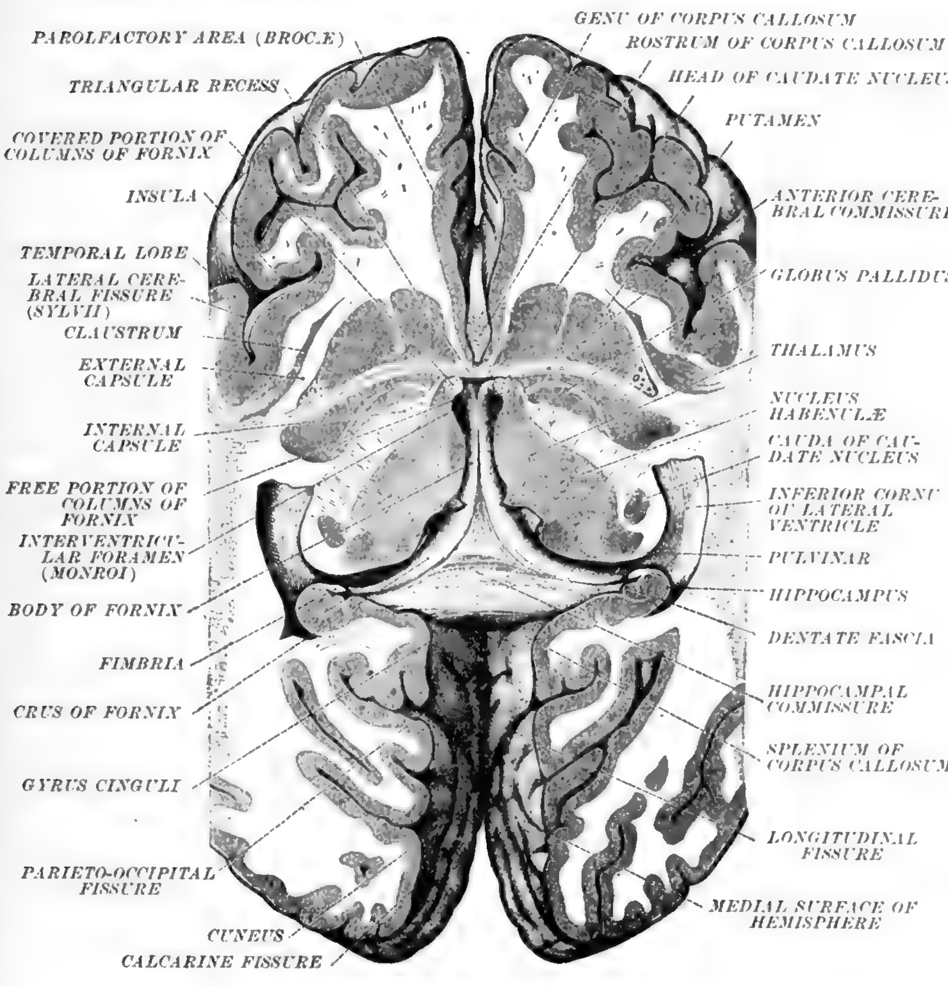
FIG. 630.—DIAGRAM OF COURSE OF FORNIX AS VIEWED FROM THE SIDE.



and laterally from the upper surfaces of the thalami. Its sharp lateral edge or margin (tænia fornicis) projects into the lateral ventricle of either side in relation with the chorioid plexus of that ventricle, and thus the lateral portion of its upper surface forms part of the floor of the lateral ventricle—an arrangement to be expected, since the posterior pillars arise from the floor of the ventricle, viz., the hippocampus. The ventricular portion is covered by a layer of ependyma in common with that lining the rest of the ventricle.

The anterior columns or pillars of the fornix are two separate, cylindrical bundles which pass forwards from the apex of the body of the fornix and then turn sharply downwards along the anterior boundary of the third ventricle, just behind the anterior cerebral commissure. A part of each column, the *free portion*, forms the anterior boundary of the interventricular foramen (Monroi). Thence it sinks into the grey substance of the lateral wall of the third ventricle (the *covered portion*), and passes ventralwards to the base of the brain, where it appears on the exterior as the **corpus mammillare** (fig. 619). Some of its fibres are interrupted in the nuclei of the corpus mammillare, chiefly in its lateral nucleus; probably most of them merely double back, forming a genu. From the corpus mammillare the fibres are disposed in

FIG. 631.—HORIZONTAL SECTION OF TELENCEPHALON SHOWING BODY OF FORNIX AS SEEN FROM BELOW AND THE ANTERIOR COMMISSURE IN SECTION. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



at least three ways:—(1) The greater part perhaps pass directly upwards and are lost in the *anterior nucleus of the thalamus*, where they ramify freely and terminate among its cells. These fibres form the bundle known as the **thalamo-mammillary fasciculus,** or bundle of Vicq d'Azyr; (2) a portion of the fibres join the cerebral peduncle near by as the **pedunculo-mammillary fasciculus,** and pass caudalwards. The destination of these is still obscure. Probably they go to the interpeduncular ganglion, the red nucleus, and the nuclei of the medulla oblongata; (3) a portion of the fibres decussate in the basal or dorsal parts of the corpora mammillaria and are distributed to both the thalamus and cerebral peduncle of the opposite side.

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The fornix proper is composed of longitudinally directed fibres, some of which, however, cross the mid-line in the region of its body and course in the columns of the opposite side. For the greater part, its fibres rise from the cells of the hippocampal gyri, but it is known to contain some fibres which arise in the structures of the olfactory lobe proper and course through the fornix to the hippocampal gyri.

The anterior cerebral commissure is only in part concerned in the rhinencephalon; it consists in greater part of commissural fibres connecting the two temporal lobes. It forms one of the three commissures of the telencephalon, the other two being the corpus callosum and the hippocampal commissure. It is a bundle of white substance with a slightly twisted appearance, which crosses the mid-line in the anterior boundary of the third ventricle between the lamina terminalis and the anterior columns of the fornix (fig. 619), just below the interventricular foramen (foramina of Monro). In each hemisphere its main or temporal portion passes outwards and slightly backwards beneath the head of the caudate nucleus and through the anterior end of the lenticular nucleus, and thence is dispersed to the grey substance of the temporal lobe. It contains fibres both to and from the temporal lobe of each side. In addition to these fibres the anterior commissure carries in its frontal side two sets of fibres belonging to the olfactory apparatus:—(1) fibres arising in the olfactory bulb of one side, which pass by way of the medial olfactory striæ through it to the olfactory bulb of the opposite side; (2) fibres which pass through it from the medial stria (olfactory bulb) of one side to the uncus of the opposite side.

The anterior commissure is a more primitive commissure than the corpus callosum, in that it is present in the lower forms when the latter is absent, and diminishes in relative size and importance as the corpus callosum appears and increases in size. In man the appearance of the anterior commissure precedes but little that of the corpus callosum. During the fifth month the lamina terminalis, which then alone unites the anterior ends of the two hemispheres, developes a thickening of its dorsal portion. In a part of this thickening, transverse fibres begin to appear and their increase in number results in the partial separation posteriorly of the part containing them from the rest of the lamina, and then follows the differentiation of this part into the anterior commissure. The remainder of the thickening of the lamina continues to increase in size with the increase of the hemispheres; its upper edge is directed posteriorly, and fibres begin to appear in it which arise in the cortex of one side and cross over to that of the other side. These fibres form the corpus callosum.

The corpus callosum, a development of fibres in the upper, expanded portion of the lamina terminalis, thus bridges over a portion of the longitudinal fissure between the hemispheres. In the mean time, the *fornix* arises as two bundles of fibres, one from the hippocampus of each side. In the complex mechanics of the development of the cerebrum these two bundles approach each other under the corpus callosum, fuse for a certain distance, and together arch over the cavity of the third ventricle and come to acquire their adult position. There results from these processes of growth a completely enclosed space, a portion of the longitudinal fissure, the roof of which is the corpus callosum, its floor, the body of the fornix, and its lateral walls, portions of the mesial surfaces of the two cerebral hemispheres. The lateral walls of this space do not thicken as do the other regions of the pallium, but remain thin and constitute the *septum pellucidum* of the adult, the space itself being the so-called *fifth ventricle* or cavity of the septum pellucidum.

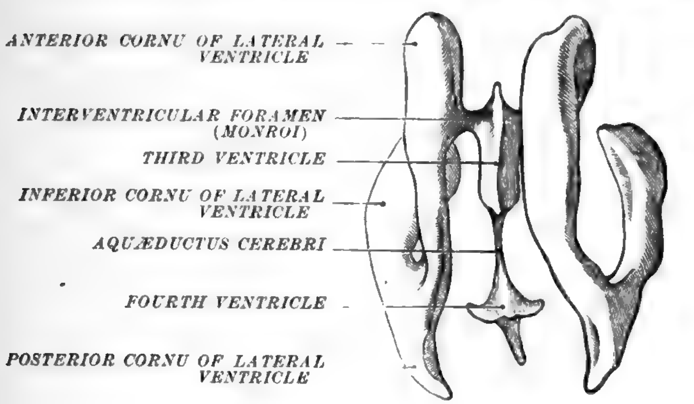
The **septum pellucidum** is a thin, approximately triangular, vertically placed partition which separates the anterior portions of the two lateral ventricles from each other. Its widest portion lies in front, bounded by the genu and rostrum of the corpus callosum, the rostral lamina, and the anterior columns of the fornix, to all of which it is attached. Prolonged backwards under the body of the corpus callosum, it narrows rapidly and terminates at the line of adherence between the posterior portion of the fornix and the splenium of the corpus callosum. It consists of two thin layers, the **laminæ of the septum pellucidum,** arrested developments of portions of the pallium of the hemispheres. The laminæ enclose a narrow median cavity known as the **fifth ventricle** (*cavity of the septum pellucidum*). This cavity is of very variable size, is completely closed, and does not merit the term 'ventricle,' as applied to the other cavities of the brain, in that it has no communication with the ventricular system and has a different lining from the other ventricles.

Each lamina of the septum pellucidum consists of a layer of degenerated grey substance next to the fifth ventricle and a layer of white substance next to the lateral ventricle, the latter covered by a layer of ependyma common to that ventricle. The white substance consists in part of fibres belonging to the general association systems of the hemispheres, and in part of two varieties of fibres concerned with the rhinencephalon:—(1) fibres from each medial olfactory stria are known to reach the septum pellucidum and thence go by way of the fornix to the hippocampus major; (2) fibres are thought to be contributed by the fornix to the septum pellucidum, and through it reach the subcallosal gyrus and perhaps the parolfactory area and even the olfactory bulb.

THE LATERAL VENTRICLES

Two of the four cavities of the ventricular system of the brain are in the telencephalon. Form their position, one in each cerebral hemisphere, they are known as the **lateral ventricles.** They arise as lateral dilations of the cavity of the anterior of the primary vesicles, and, just as the fourth ventricle remains in communication with the third by way of the aquæductus cerebri, so the lateral are connected with the third by the two interventricular foramina (Monroi). The whole ventricular system, including the central canal of the spinal cord, is lined

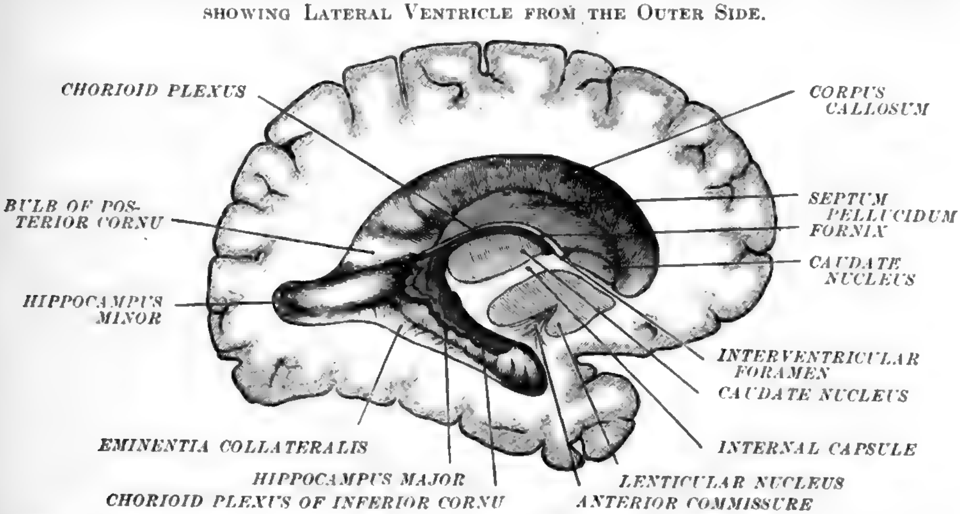
Fig. 632.—A Cast of the Four Ventricles of the Encephalon. (After Welcker.)



by a continuous layer of ependyma and contains a small quantity of lymph known as the *cerebro-spinal fluid.*

Each lateral ventricle is of an irregular, horseshoe shape. It consists of a central portion or body and three cornua, which correspond to the three poles of the hemisphere. The portion projecting into the frontal lobe is known as the anterior cornu, that projecting into the occipital lobe is the posterior cornu, and the portion which sweeps downwards into the temporal lobe is the inferior cornu. The ventricles of dif-

Fig. 633.—Diagram of Sagittal Section through Lateral Part of Right Hemisphere showing Lateral Ventricle from the Outer Side.



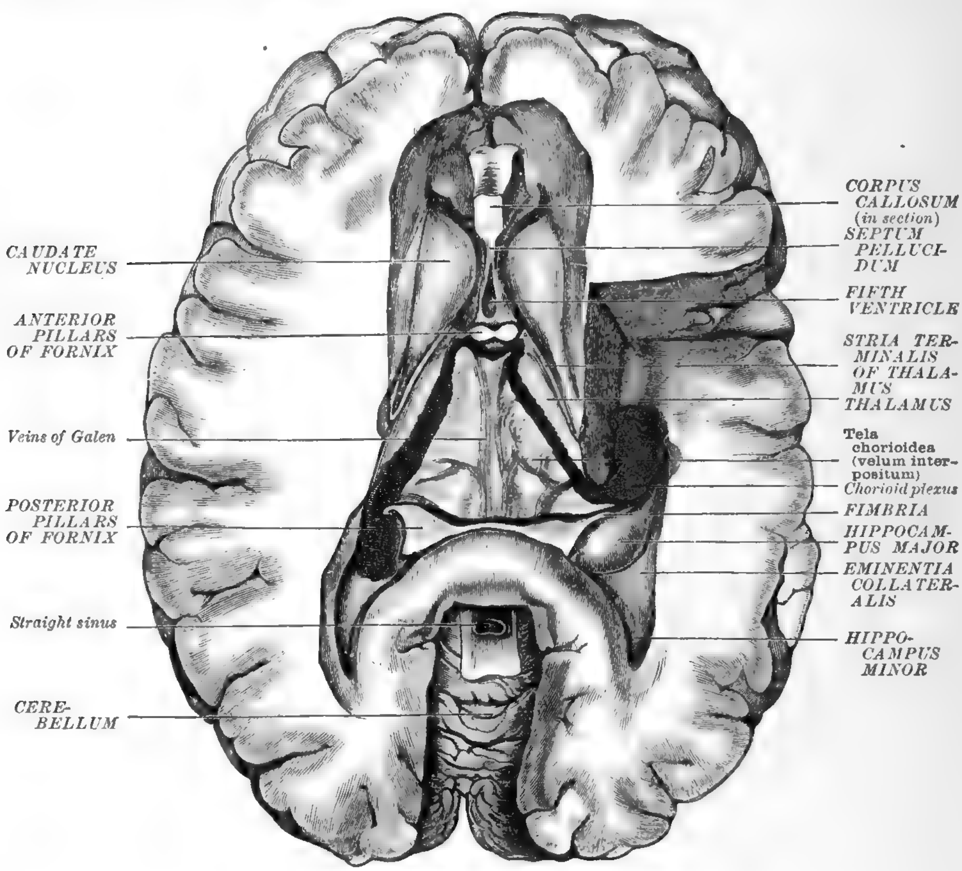
ferent individuals vary considerably in capacity, and the cavity of a given ventricle is not uniform throughout. In some localities the space may be quite appreciable, while in other places the walls may be approximate or even in apposition. Each lateral ventricle is a completely closed cavity except at the interventricular foramen. However, a strip of the floor of the inferior cornu is separated from the exterior of the brain by only the thin, non-nervous lamina forming the floor of the chorioid fissure.

The **interventricular foramen** (foramen of Monro), by which the lateral ventricle is continuous with the cavity of the third ventricle, is a small, roundish channel, 2 to 4 mm. wide, which opens into the mesial side of the posterior end of the anterior cornu. It is bounded in front by the free portion of the anterior pillars of the fornix, and behind by the anterior tubercle of the thalamus. That the greater part of the lateral ventricle is posterior to it is due to the backward extension of the hemispheres during their growth and elaboration. Through the two foramina indirectly, the cavities of the two lateral ventricles are in communication with each other.

The walls of the lateral ventricle.—The **anterior cornu** is a bowl-like cavity, convex forwards and extending upwards and medianwards into the frontal lobe.

FIG. 634.—HORIZONTAL DISSECTION OF THE CEREBRAL HEMISPHERES.

The fornix has been removed to show the relation of the tela chorioidea of the third ventricle to the chorioid plexus of the lateral ventricles. (From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)



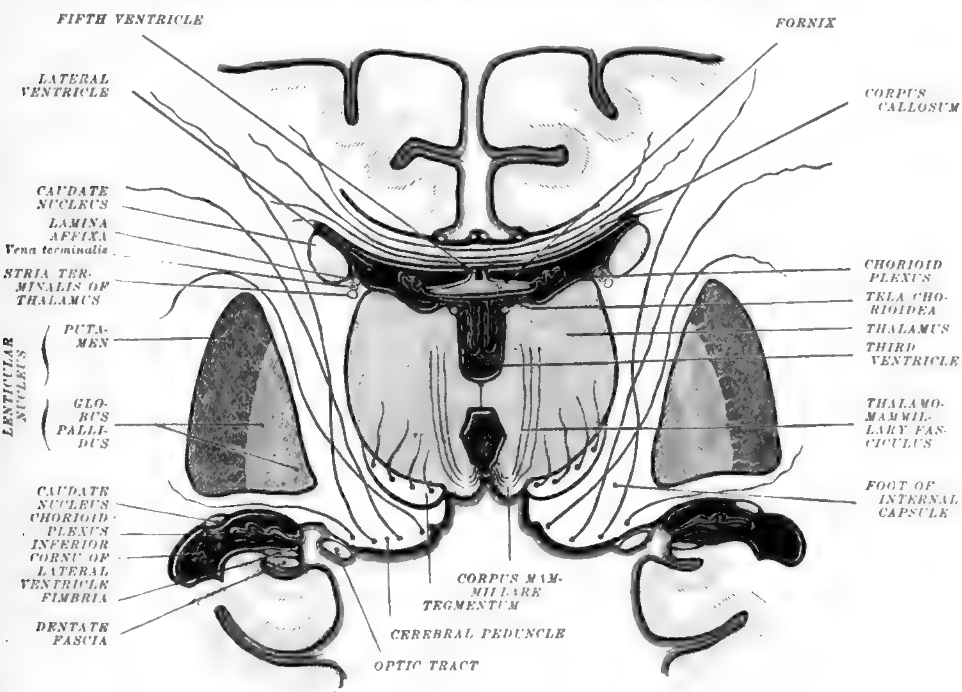
Above and anteriorly it is bounded by the under surface of the corpus callosum and the radiations of its genu into the substance of the frontal lobe. Its median boundary is the septum pellucidum; the head of the caudate nucleus (part of the corpus striatum) gives it a bulging, ventro-lateral wall, and the balance of its floor is formed by the white substance of the orbital part of the frontal lobe.

The **body** or **central portion** is more nearly horizontal. It lies within the parietal lobe and extends from the interventricular foramen to the level of the splenium of the corpus callosum. Its roof is formed by the inferior surface of the body of the corpus callosum, and its mesial wall consists of the posterior part of the septum pellucidum, attaching the fornix to the under surface of the corpus callosum. Like the anterior horn, it is given an oblique, ventro-lateral wall by the narrower,

middle part of the caudate nucleus. Several structures contribute to its floor:—(1) the stria terminalis of the thalamus, a line of white substance conforming to the genu of the internal capsule without, and constituting the boundary between the caudate nucleus and the thalamus, and containing (2) the vena terminalis (vein of the corpus striatum); (3) the lamina affixa, a medial continuation of the stria terminalis upon the surface of (4) the lateral part of the thalamus; (5) the medial edge of the lamina affixa, the tænia chorioidea, and the chorioid plexus continuing under (6) the edge (tænia) of the body and the beginning posterior pillars of the fornix.

The chorioid plexus of the lateral ventricle is continuous with that of the third ventricle. The tela chorioidea of the third ventricle (velum interpositum) continues under the tænia of the fornix into the lateral ventricle, and there, along the line of the tænia chorioidea, becomes elaborated into a varicose, convoluted, villus-like fringe, rich in venous capillaries and lymphatics. This fringe is the chorioid plexus. It is continuous in front, at the interventricular foramen, with the corresponding plexus of the opposite lateral ventricle and with the chorioid plexus of the third

Fig. 635.—Diagrammatic Transverse Section of Prosencephalon through Bodies of Lateral Ventricles and Middle of Thalamencephalon.



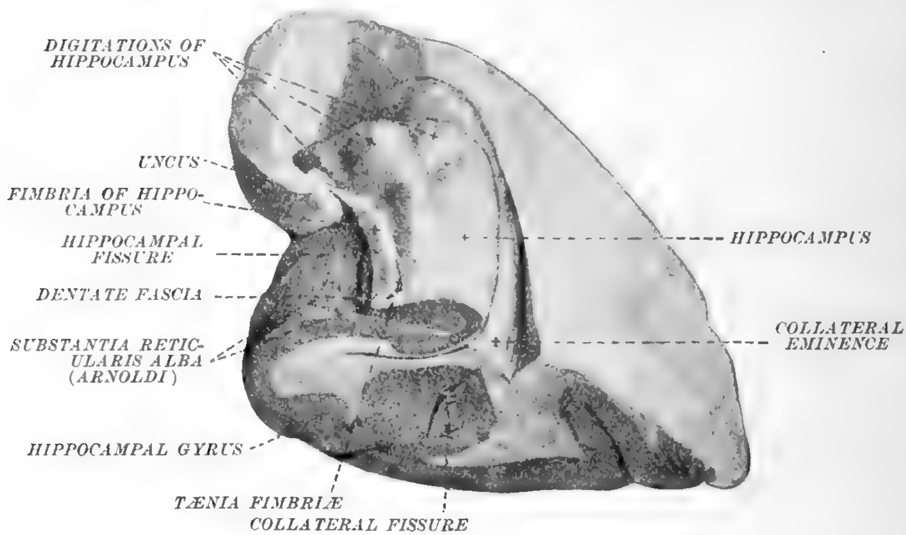
ventricle. The latter consists of two similar but smaller fringes, which project close together into the cavity of the third ventricle from the median portion of the under surface of the tela chorioidea. Behind, the chorioid plexus of the lateral ventricle curves backwards and downwards into the inferior cornu, being especially well-developed at the region of its entrance into the latter, into what is called the **glomus chorioideum.** Though apparently lying free in the ventricle, the chorioid plexus is invested throughout by a layer of epithelium, the **epithelial chorioid lamina,** which is adapted to all its unevennesses of surface and which is a continuation of the ependymal lining of the remainder of the ventricle,—continuous, on the one hand, with that of the lamina affixa and thalamus, and, on the other, with the epithelial covering upon the upper surface of the tænia fornicis and fimbria.

The **posterior cornu** of the lateral ventricle is a crescentic cleft of variable length, convex outwards, which is carried backwards from the posterior end of the body of the ventricle and, curving medianwards, comes to a point in the occipital lobe. Its *roof* and *lateral wall* are formed by a portion of the posterior radiation of the corpus callosum, which forms a layer, from its appearance known as the **tapetum.** In trans-

verse sections of the occipital lobe (fig. 643) the tapetum appears as a thin lamina of obliquely cut white substance immediately bounding the cavity, while outside the tapetum occurs a thicker layer of more transversely cut fibres, the occipito-thalamic radiation. In the medial or *inner wall* of the posterior horn run two variable longitudinal eminences:—(1) The superior of these is the **bulb of the posterior cornu,** and is formed by the occipital portion of the radiation of the corpus callosum (splenium), which bends around the impression of the deep parieto-occipital fissure, and, hook-like, sweeps into the occipital lobe. In horizontal sections these fibres, together with the splenium and the similar fibres into the opposite occipital lobe, form the figure known as the **forceps major.** (2) The inferior and thicker of the eminences is the **hippocampus minor** or **calcar avis** (cock's spur), and is due to the anterior part of the calcarine fissure, by which the wall of the hemisphere is projected into the ventricle. The posterior horn, like the anterior, is not entered by the chorioid plexus.

The inferior cornu.—In its inferior and slightly lateral origin from the region of junction between the body of the ventricle and the posterior cornu, the inferior horn aids in producing a somewhat triangular dilation of the cavity known as the **collateral trigone.** Beginning as a part of the trigone, the cavity of this horn at first passes backwards and lateralwards, but then suddenly curves downwards and for-

FIG. 636.—DISSECTION OF RIGHT TEMPORAL LOBE SHOWING THE MEDIAL WALL OF THE END OF THE INFERIOR HORN OF THE LATERAL VENTRICLE. (From Spalteholz.)



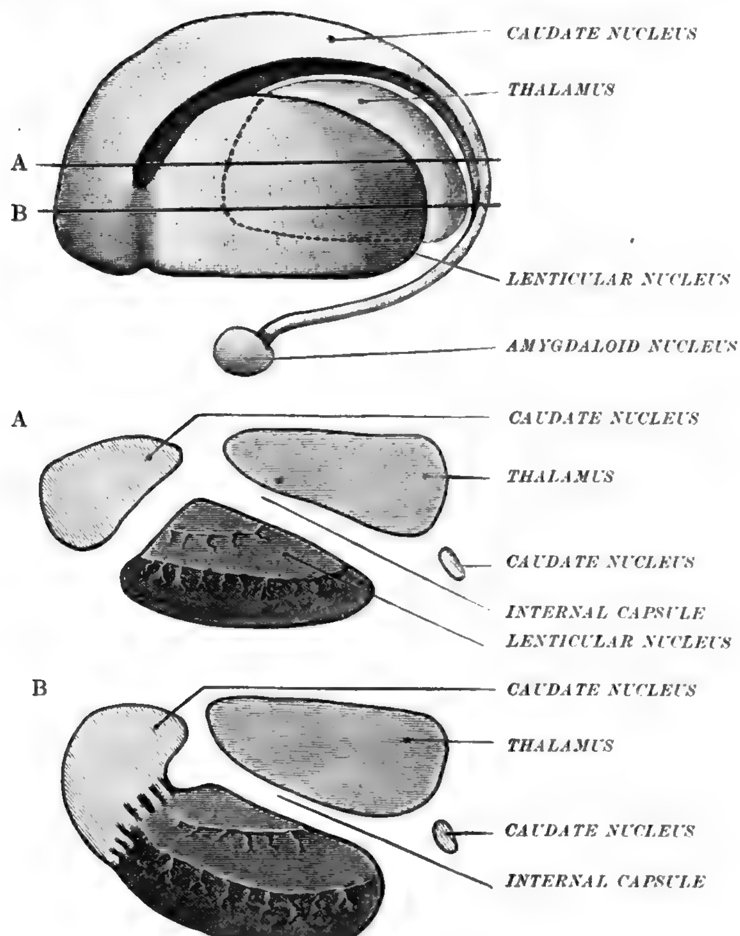
wards into the medial part of the temporal lobe nearly parallel with the superior temporal sulcus. Above, it follows the curve of the posterior pillars of the fornix and fimbria; below, it does not extend to the temporal pole by from 2 to 3 cm. The *roof* and *lateral wall* are, for the most part, like those of the posterior horn, being formed by the tapetum, but medianwards a strip of the roof is formed by the attenuated, inferior prolongation, or tail, of the caudate nucleus, together with the lower part of the stria terminalis of the thalamus. At the end of the inferior horn the roof shows a bulging, the **amygdaloid tubercle,** situated at the termination of the tail of the caudate nucleus. This bulging is produced by the *amygdaloid nucleus*, an accumulation of grey substance continuous with that of the cortex of the temporal lobe, and which gives origin to the greater part of the longitudinal fibres coursing in the stria terminalis of the thalamus.

In the *medial wall* and floor of the inferior horn the following structures are shown:—(1) In the posterior or trigonal part of the floor is the longitudinal **collateral eminence,** a bulging, very variable in development in different specimens, produced by the collateral fissure. This is often pronouncedly in two parts, a posterior prominence corresponding to the middle portion of the collateral fissure and an anterior prominence (less frequent) produced by the anterior part of the fissure. (2) Medial to this eminence lies the inferior extension of the **chorioid plexus,** usually more vol-

uminous than the part in the body of the ventricle. (3) Partly covered by the chorioid plexus is the **hippocampus major,** a prominent, sickle-like ridge corresponding to the indentation of the hippocampal fissure. It begins as a narrow ridge behind, at the end of the body of the ventricle, as the extension of the posterior pillar of the fornix, and expands in front as the ventricular surface of the uncus. Its surface is not regular, but shows a concave medial margin as distinguished from a wider, convex, lateral surface. Its termination in front (*pes hippocampi*) is divided by two or three flat, radial grooves into a corresponding number of short elevations known as the *hippocampal digitations*. It is covered by a thick stratum of white substance, the

Fig. 637.—Diagrams of Lateral View and Sections of the Nuclei of the Corpus Striatum with the Internal Capsule Omitted.

A and B below represent horizontal sections along the lines A and B in the figure above. The figure also shows the relative position of the thalamus and the amygdaloid nucleus.



alveus, arising from its depths and continued mesially into the fimbria. (4) The **fimbria** is so folded that its margin, *tænia fimbriæ*, lies in the cavity of the inferior horn attached to the chorioid plexus and the thin, non-nervous floor of the chorioid fissure.

The caudate nucleus.—As realised in the study of the lateral ventricle, the caudate nucleus is a comma-shaped mass of grey substance with a long, much-curved, and attenuated tail. Its *head* forms the bulging lateral wall of the anterior horn; thence it proceeds backwards in the lateral wall of the body of the ventricle and, at the collateral trigone, curves downwards and its *tail* becomes a median portion of the roof of the inferior horn. It is separated from the thalamus adjacent to it by the stria

terminalis of the thalamus (tænia semicircularis). The end of its tail extends forwards below to the level of the anterior horn of the ventricle above. Owing to its much curved shape, both horizontal and vertical sections of the hemisphere passing through the inferior horn may contain the nucleus cut at two places (see fig. 640). The caudate nucleus is the intraventricular of the two masses of grey substance which together are sometimes referred to as the *basal ganglia*. The extraventricular of these masses is the *lenticular nucleus*, which is buried in the substance of the hemisphere, laterally and below the caudate nucleus. The two masses are separated by the *internal capsule*, a thick band of nerve-fibres continuous into the cerebral peduncles, and connecting the grey cortex of the hemisphere with the structures below it. Anteriorly and below, the two nuclei become continuous and the white substance of the internal capsule, in separating them posteriorly, contributes to their striated appearance in sections, whence they are known collectively as the *corpus striatum* (figs. 638 and 641). The corpus striatum as such is described below.

Internal structure of the prosencephalon.—From the above examinations of their external and ventricular surfaces, it is apparent that the cerebral hemispheres consist of a folded, external coating of grey substance, the cortex cerebri, spread more or less evenly over an internal mass of white substance which contains embedded within it certain masses of grey substance, the chief of which are known as the basal ganglia or the caudate and lenticular nuclei of the corpus striatum. In addition, the hemispheres of the telencephalon overlie and are in functional connection with the structures of the diencephalon below, the chief of which are the thalamencephalon and the cerebral peduncles.

The grey substance of the telencephalon.—The grey substance is in intimate relation with the white substance, and in fact its cells give origin to the greater part of the fibres composing the white substance. The accumulations of grey substance to be considered are the cerebral cortex, with its variations in thickness and arrangement, the corpus striatum, the claustrum, and the amygdaloid nucleus.

The cerebral cortex is distributed over the entire surface of each hemisphere except the peduncular region of the base and the region of the corpus callosum and fornix of the medial surface. Numerous measurements have been made to determine its average thickness. These have shown that it is not uniformly distributed:—(1) that it is thicker on the convex surface than on the basal and medial surfaces; (2) that on the convex surface it is thicker on the central region of the hemisphere, somæsthetic area, than at the poles; (3) that in the average normal specimen it averages somewhat thicker on the left than on the right hemisphere; (4) that its average thickness varies greatly in different individuals, and that the thickness decreases with old age; (5) that it is probably somewhat thicker in males than in females, and (6) that in a given specimen it averages thicker on the summits of the gyri than in the floor of the corresponding sulci. In the normal adult conditions it averages about 4 mm. thick on the anterior and posterior central gyri, in the somæsthetic area, while it attains its mimimum thickness of about 2·5 mm. on the basal surface of the occipital and frontal lobes. Its total average thickness is about 2·9 mm.

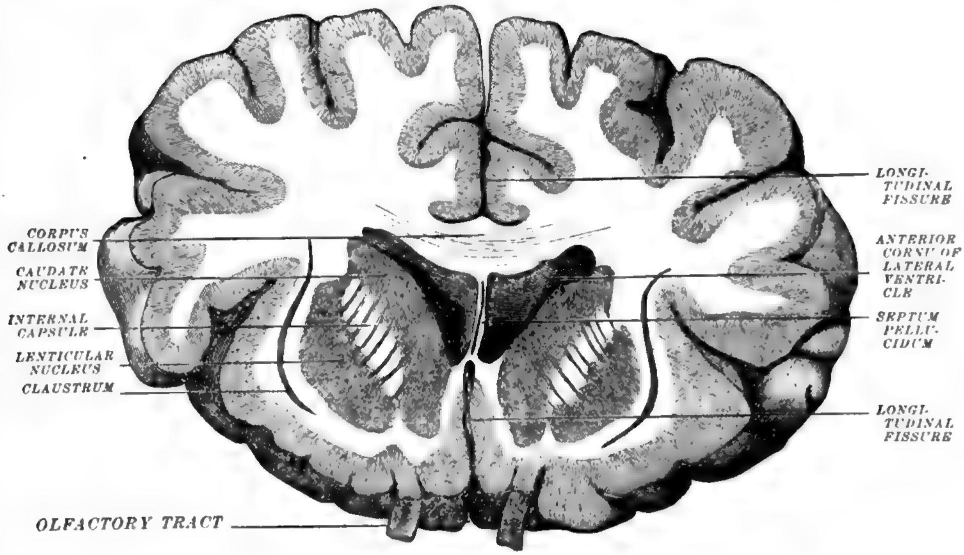
The cortex consists of layers of the cell-bodies of neurones, chiefly of the pyramidal type (fig. 555), which receive impulses from the structures below and from other regions of the cortex by way of fibres reaching them through the internal mass of white substance, and which in turn contribute fibres to the white substance. Certain fibres of shorter course and numerous collateral branches of fibres passing out of the cortex are devoted to the association of the region of their origin with the cortex of the immediate vicinity of their origin, and most of these course within the grey cortex itself. In certain gyri, such as the anterior central gyri and those of the medial surface of the occipital lobe, these short association fibres accumulate into strata, and in vertical sections give the cortex a stratified appearance. Two such strata of white substance may be noted in the above localities, one lying about midway in the thickness of the cortex and one slightly internal to this. They are known as the inner and outer **stripes of Baillarger.** In addition, a thin, superficial or *tangential layer* of fibres may often be distinguished lying in the outermost region of the cortex. Transverse sections through the anterior end of the hippocampus show a coiled arrangement of the layers of white substance, to which has been given the name *cornu ammonis*. The peculiar structure and appearance of the olfactory bulb and tract, parts of the cortex, have already been mentioned.

The corpus striatum is the name given to the appearance in section of the caudate and lenticular nuclei (basal ganglia) and the internal capsule between them. The two nuclei are directly continuous with each other at their anterior ends (fig. 637), and in addition they are connected by numerous small bands of grey substance which

pass from one to the other through the internal capsule, especially its anterior part. Also each nucleus contributes numerous fibres to, and receives fibres from, the internal capsule. These bundles of fibres both arising and terminating within the nuclei, together with the grey substance among the fibres of the capsule, produce the ribbed and striped appearance suggesting the name, corpus striatum. The **caudate nucleus**—the intra-ventricular part of the corpus striatum—lies with its thicker anterior part (head) closely related to the internal capsule, but its tail passes backwards around the posterior border of the capsule and curves downwards and forwards into the roof of the inferior cornu of the lateral ventricle.

The lenticular nucleus (nucleus lentiformis)—the extraventricular part of the corpus striatum—is embedded in the white substance of the cerebral hemisphere. It is somewhat pyriform in shape, not being so long as the caudate nucleus, and neither having a tail nor extending so far forwards. Its lower surface is separated from the inferior cornu of the lateral ventricle by the white substance of the roof of that cornu, and by the tail of the caudate nucleus, and, further forwards, the anterior commissure passes through its base. Its outer surface is rounded and conforms both in extent and curvature with the surface of the insula, from which it is separated by the fibres

FIG. 638.—CORONAL SECTION OF TELENCEPHALON PASSING THROUGH FRONTAL LOBES AND ANTERIOR PORTION OF CORPUS STRIATUM.
(From mounted specimen in the Anatomical Department of Trinity College, Dublin.)



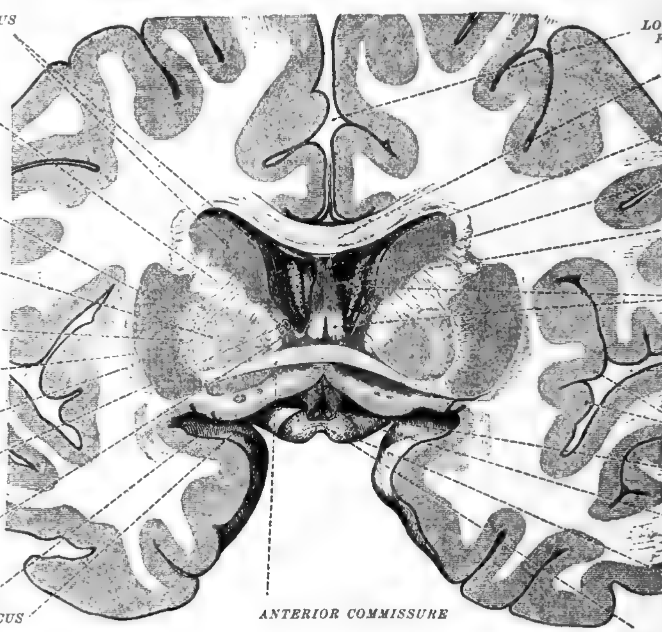
of the external capsule and the intervening claustrum. Its oblique upper and inner surface is adapted to the outer surface of the internal capsule, and it comes to a rounded apex in the angle formed by the internal capsule and a plane parallel with the base of the hemisphere. In both horizontal and coronal (transverse) sections through its middle it resembles a compound biconvex lens. Internally this appearance is produced by two vertically curving laminæ of white substance, an **external** and an **internal medullary lamina,** which divide its substance into three zones:—the two inner zones together form an area, triangular in section, known as the **globus pallidus;** the outer, larger and darker, concavo-convex zone is the **putamen.** Radiating fibres from the medullary laminæ extend into the zones, especially those of the globus pallidus. These zones disappear in transverse sections of the anterior portion of the lenticular nucleus (fig. 638), due to the fact that the larger putamen alone comprises this portion and alone becomes continuous with the caudate nucleus.

Connections.—Both nuclei of the corpus striatum become continuous with the cortex in the region of the anterior perforated substance, and the putamen of the lenticular nucleus may blend with the anterior part of the base of the claustrum. The following are the principal fibre connections:—(1) Fibres arising in the nuclei which join the internal capsule to reach the cerebral cortex, and fibres arising in the cortex which descend by the same course to the cells of the

nuclei. (2) Fibres which pass in both directions between the thalamus and the corpus striatum (caudate nucleus especially). These are more abundant anteriorly, and necessarily pass through the internal capsule. (3) The **ansa lenticularis,** a usually distinct bundle, composed largely of fibres passing between the thalamus and lenticular nucleus. It passes from the under aspect of the anterior tubercle of the thalamus and curves below through the internal capsule to the under surface of the lenticular nucleus, and there its fibres are distributed upwards through its medullary lamina to the globus pallidus and putamen. Some enter the internal capsule and reach the cortex, chiefly that of the temporal lobe. (4) Fibres connecting both nuclei (chiefly the caudate) with the substantia nigra of the mesencephalon. These pass through the hypothalamic region and along the cerebral peduncle.

The claustrum is a triangular plate of grey substance which is embedded in the white substance between the lenticular nucleus and the insula. Its inner surface is concave, conforming to the convexity of the putamen. The sheet of white substance intervening between it and the putamen is known as the **external capsule.** Its outer surface shows ridges or projections in section which conform to the neighbouring gyri of the insula, and it is spread through an area which quite closely corresponds to that of the insula. Below and anteriorly it becomes continuous with the cortex

Fig. 639.—Coronal Section of Telencephalon through the Anterior Commissure, Optic Chiasma, and Trunk of Corpus Callosum. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



of the anterior perforated substance and with the lenticular nucleus at the region of its junction with the latter. Above and posteriorly it gradually becomes thinner, and finally disappears in the white substance about it. In origin it is thought to be a detached portion of the cortical grey substance of the insula.

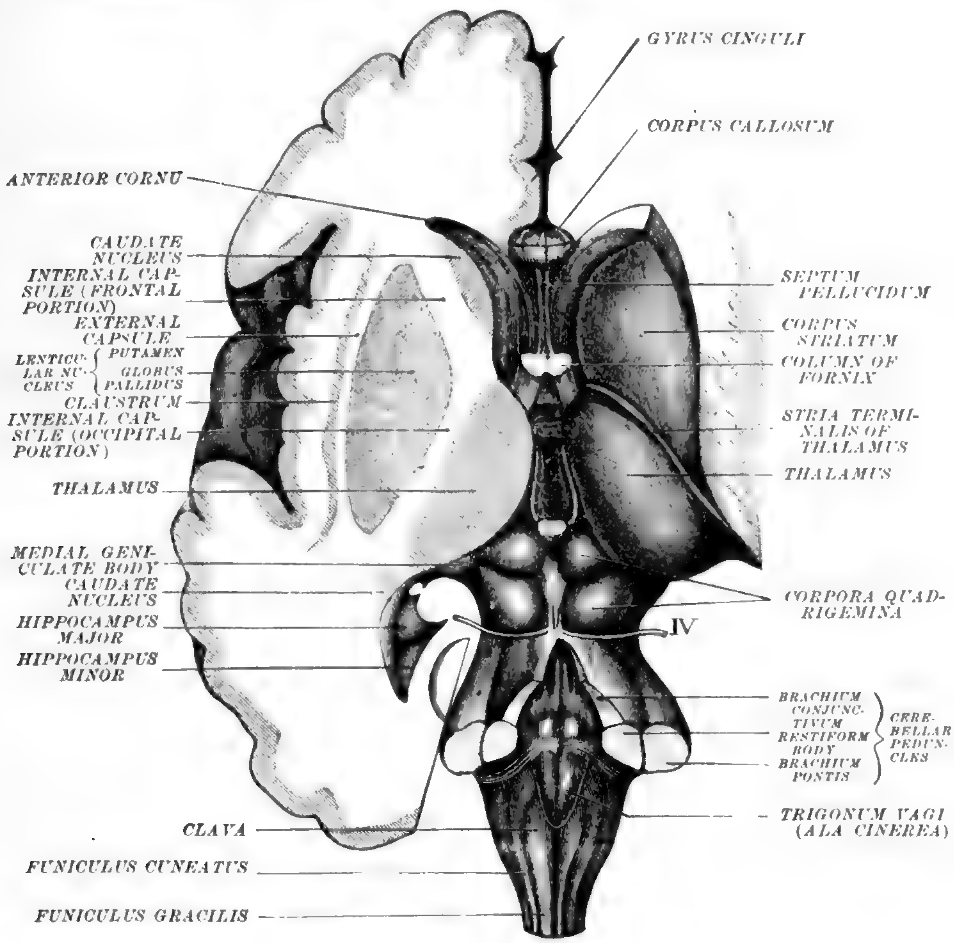
The amygdaloid nucleus (nucleus amygdalæ) is represented by the amygdaloid tubercle, which has already been described in the extremity of the inferior cornu of the lateral ventricle (figs. 614 and 637). It is an almond-shaped mass of cells joined to the tail of the caudate nucleus, continuous above with the putamen and anteriorly with the cortex of the temporal lobe.

Apparently the chief connection of the amygdaloid nucleus is with the anterior perforated substance, and this by way of the *stria terminalis of the thalamus.* The longitudinal fibres coursing in this bundle for the most part arise in the nucleus. Thence they pass backwards in the roof of the inferior cornu, then curve upwards and anteriorly just outside the pulvinar of the thalamus, and run in the floor of the body of the lateral ventricle along the line of the genu of the internal capsule, forming the boundary between the thalamus and the caudate nucleus (figs. 614 and 638). Upon reaching the anterior commissure, the fibres turn ventrally and disperse, and are said to terminate in the anterior perforated substance. The amygdaloid

nucleus, like the claustrum, is thought to represent a detached portion of the cortex—probably from the region of the uncus. Considering this and its chief connection, it may be concerned in the central portion of the olfactory apparatus with the stria terminalis, which thus may be somewhat homologous to the fornix.

The thalamus and hypothalamus.—The external features of these portions of the prosencephalon have been described in their natural place, but inasmuch as they contain the chief relays and connections between the telencephalon and the divisions of the nervous system below the prosencephalon, the consideration of their internal structure has been deferred till now. The principal grey masses to be considered are the thalamus and the hypothalamic nucleus. The structures of the metathalamus

Fig. 640.—Horizontal Dissection showing the Grey and White Substance of the Telencephalon Below the Corpus Callosum and the Relative Position of the Thalamencephalon. (After Landois and Stirling.)



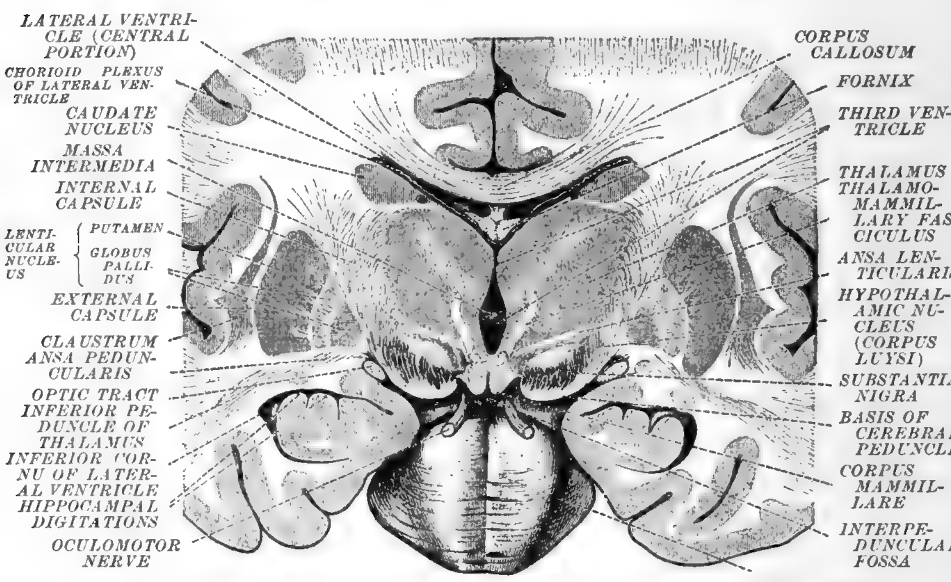
and epithalamus have already been mentioned in their relations with the mesencephalon and the optic and auditory apparatus.

The thalamus has upon its upper surface a thin **stratum zonale** of white substance, derived in part from the optic tract and in part from its own cells. Its oblique lateral surface conforms to the inner surface of the internal capsule; its vertical medial surface forms the lateral wall of the third ventricle, and below it is continuous into the hypothalamic (tegmental) region. Its dorsal surface shows a middle, an anterior, and a posterior prominence or tubercle. The **anterior tubercle** forms the posterior boundary of the interventricular foramen; the posterior tubercle is the cushion-like **pulvinar** which projects backwards over the lateral geniculate body and the brachium of the anterior quadrigeminate body.

A horizontal section through the tænia thalami, splitting the stria medullaris and thus passing above the massa intermedia, shows the grey mass of the thalamus divided into segments or nuclei by a more or less distinct **internal medullary lamina.** This extends the whole length of the thalamus, dividing its middle and posterior portion into the **medial** and the **lateral nucleus.** In front the lamina bifurcates into a medial limb, extending to the medial surface of the thalamus, and a lateral limb, extending forwards to join the genu of the internal capsule (fig. 641). This bifurcation results in a cup-like sheet of white substance which encloses the **anterior nucleus.** On the external surface, next to the internal capsule, there may usually be distinguished an **external medullary lamina,** separated from the white substance of the capsule by a *reticular layer* of mixed white and grey substance.

The anterior nucleus, lying partially encapsulated in the bifurcation of the internal medullary lamina, is somewhat wedge-shaped and points backwards between the front portions of the lateral and medial nuclei. It is composed chiefly of large cells, and constitutes the anterior tubercle of the dorsal aspect. Its principal connection from below is with the nuclei of the mammillary body of the same and opposite sides, and with fibres from the anterior columns of the fornix direct. The fibres from

Fig. 641.—Coronal Section of Prosencephalon through Thalamencephalon at Region of Corpora Mammillaria. (Seen from in front.) (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



both sources enter it by way of the *thalamo-mammillary fasciculus* (figs. 619 and 641). The significance of this connection is noted in the description of the limbic lobe.

The lateral nucleus, lying between the external and internal medullary laminæ, extends backwards to include the entire pulvinar, which, as already noted, together with the lateral geniculate body, constitutes the prosencephalic nucleus of termination of the optic tract, and the stratum zonale upon the surface of this nucleus might be called the stratum opticum. The anterior portion of the lateral nucleus also receives fibres below from the red nucleus, from the brachium conjunctivum (cerebellum direct), and some fibres of the medial lemniscus terminate about its cells.

The medial nucleus lies inside the internal medullary lamina and forms the posterior portion of the lateral wall of the third ventricle. It is shorter than the lateral nucleus, and is less extensively pervaded by fibres. It is thought to receive fibres from the red nucleus, and perhaps some from the lemniscus, and is usually continuous across the third ventricle with the opposite medial nucleus by the massa intermedia.

All the nuclei of the thalamus are connected with the lenticular nucleus by fibres

passing between the two through the internal capsule directly, and by fibres curving from below, chiefly from the lateral and medial nuclei, and passing in the ansa lenticularis.

The cortical connections of the thalamus are abundant. They consist of fibres both to and from the cortex of the different lobes of the hemisphere, the greater part arising in the thalamus and terminating in the cortex. These fibres collect in the internal and external medullary laminæ and the stratum zonale; most of them enter the internal capsule and thence radiate to the different parts of the cortex. They form the so-called peduncles of the thalamus, which have been distinguished both by the Flechsig method of investigation and by the method of degeneration. The anterior or **frontal peduncle** passes from the lateral and anterior part of the thalamus through the frontal portion of the internal capsule, and radiates to the cortex of the frontal lobe. The middle or **parietal peduncle** passes from the lateral surface of the thalamus through the intermediate part of the internal capsule, and upwards to the cortex of the parietal lobe. The posterior or **occipital peduncle** passes chiefly from the pulvinar, through the occipital portion of the internal capsule, and radiates backwards to the occipital lobe by way of the occipito-thalamic (optic) radiation (fig. 643). The **inferior peduncle** passes from the inner and under surface of the thalamus (from the anterior part chiefly), turns outwards to course beneath the lenticular nucleus, and radiates to the cortex of the temporal lobe and insula. Many of the fibres of this peduncle course in the ansa lenticularis (fig. 641). Some turn upwards in the external capsule to reach the cortex above the insula.

The hypothalamic nucleus, or body of Luys, is the principal nucleus of termination of the medial lemniscus, the great sensory cerebro-spinal pathway. It contains the cell-bodies of the neurones of the third order in this pathway, those of the first order being situated in the spinal ganglia, and those of the second order in the nuclei of the fasciculus gracilis and fasciculus cuneatus. It is a biconvex mass of grey substance situated below the lateral and anterior nuclei of the thalamus, and between these and the basis of the cerebral peduncle, or rather the substantia nigra, which is spread upon the dorsal surface of the peduncle, and which, though greatly diminished, extends into the hypothalamic region. The hypothalamic nucleus presents a brownish-pink colour in fresh material, due to pigment in its cells and to its abundant capillary supply. It is enclosed by a thin capsule of white substance, some of the fibres of which seem to decussate with those of the opposite side in the floor of the third ventricle, above and just behind the region of the corpora mammillaria. By far the greater part of the fibres arising from the nucleus join the internal capsule, and through it ascend to radiate to the cortex of the pre- and post-central gyri, the sensory-motor or somæsthetic area of the hemisphere.

All the fibres connecting the cerebral cortex with both the thalamus and the hypothalamic nucleus belong to the so-called *projection fibres* of the cerebral hemisphere.

Worthy of note here are two other structures which, like the thalamus, belong to the thalamencephalic portion of the diencephalon, though mention of them and their connections has been deferred because of the fact that they are encountered in sections for the internal structure of the telencephalon, since, as usually studied, such sections are made to involve both the telencephalon and the diencephalon. These structures are the *habenular nucleus* and the *fasciculus retroflexus* of Meynert.

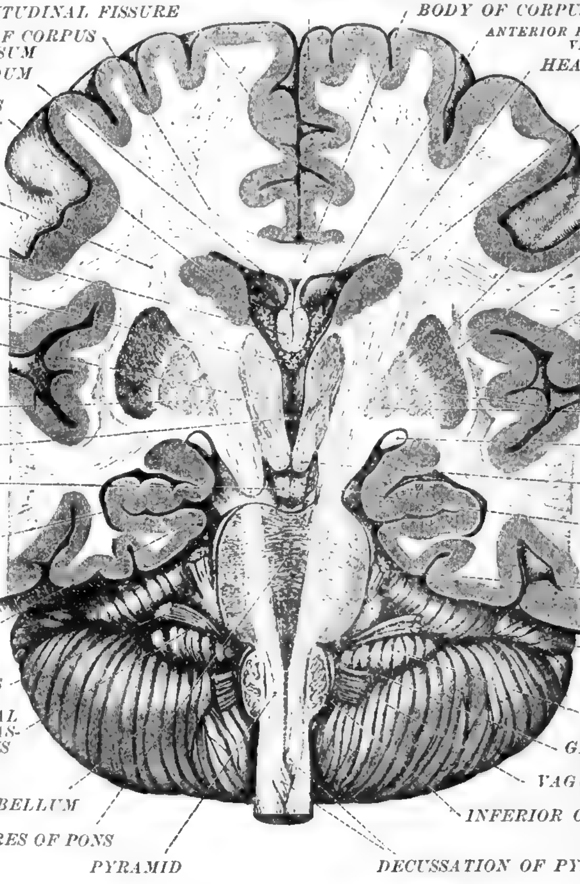
The **habenular nucleus,** a part of the epithalamus, is a small group of nerve cells situated in the substance just below and lateral to the epiphysis. A small bundle of fibres crossing the mid-line under the epiphysis in the dorsal aspect of the posterior cerebral commissure has been called the *commissura habenularum*, from the fact that it apparently connects the habenular nuclei of the two sides.

The **fasciculus retroflexus (Meynerti)** is a relatively strong bundle of medullated fibres which runs ventralwards and slightly caudalwards from the habenular nucleus towards the inferior portion of the interpeduncular fossa. It has been shown that many, at least, of the fibres of this bundle arise from the cells of the habenular nucleus. In its slightly caudad course, the bundle passes obliquely through the red nucleus, entering the mesial superior aspect and making its exit from the ventro-mesial side of the inferior extremity of this nucleus. In the animals in which it has been studied, the bundle seems to terminate in the *interpeduncular ganglion*, a group of nerve cells lying in the floor of the interpeduncular fossa at the level of the inferior quadrigemina. In man, the interpeduncular ganglion is seemingly absent as such, and the bundle seems to disappear in the posterior per-

forated substance. However, the microscope shows cells scattered among the fibres of the bundle and these cells probably represent the ganglion.

The white substance of the telencephalon.—A horizontal section through the upper part of the trunk of the corpus callosum will pass above the basal grey substance of the corpus striatum, and, aided by the corpus callosum, each hemisphere in such a section will appear as if consisting of a solid, half-oval mass of white substance, bounded without by the grey layer of the cortex (fig. 620). As seen at this level, the white substance of each hemisphere is known as the **centrum semi-ovale.** Horizontal sections passing below the body of the corpus callosum involve the corpus striatum and thalamus, and the appearance of the white substance is modified accordingly (fig. 640).

Fig. 642.—Oblique Frontal Section through the Brain in the Direction of the Cerebral Peduncles and the Pyramids. (Seen from in front.) (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



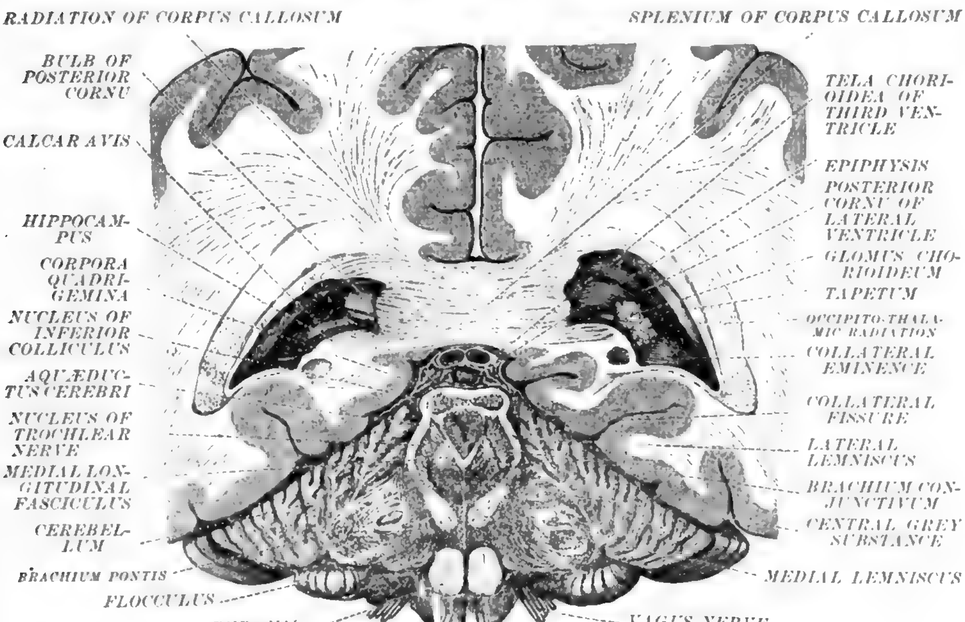
In the white substance of the cerebral hemispheres as a whole three main systems of fibres are recognised:—projection fibres, commissural fibres, and association fibres. The *projection fibres* are those of a more or less vertical course, which pass to and from the cortex of the hemisphere, connecting it with the structures below the confines of the hemisphere. The *commissural fibres* are those of a transversely horizontal course, which cross the mid-line and connect the two hemispheres with each other. The *association fibres* are those which neither cross the mid-line nor pass beyond the bounds of the hemisphere in which they arise, but instead connect (associate) the different parts of the same hemisphere—lobes with lobes and gyri with gyri. The fibres which connect the cortex with the nuclei of the corpus striatum must be classed as association fibres also, since these masses of grey substance are a part of the telencephalon, while by definition those which connect the thalamus and hypothala-

mus with the cortex belong to the projection system. Some of the fibre bundles of the above systems have already been described in connection with the parts with which they are concerned.

The projection fibres of the hemisphere comprise both ascending and descending fibres between the cerebral cortex and structures below the bounds of the hemisphere, i.e., some arise in the structures below and terminate in the cortex; others arise from the cortical cells and terminate in the structures below, including the grey substance of the thalamencephalon, mesencephalon, rhombencephalon, and spinal cord. The projection fibres are given different names in the hemisphere according to their arrangement and the appearances to which they contribute in the dissections. Beginning with the basis of the peduncle, they contribute—(1) to the *internal capsule* and some to the *external capsule* and (2) to the *corona radiata.*

The internal capsule is a band of white substance, consisting of the ascending fibres from the nuclei of the thalamus, hypothalamus, and corpus striatum, reinforced by the descending fibres from the cortex to these nuclei and by those descending in the cerebral peduncle to reach the structures below the prosencephalon. It is a

Fig. 643.—Coronal Section through the Splenium of the Corpus Callosum and the Posterior Cornua of the Lateral Ventricles. (Viewed from behind.) (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



broad, fan-like mass of fibres, which increases in width from the base of the hemisphere upwards, and which is spread between the lenticular nucleus on its outer side and the caudate nucleus and thalamus on its inner side. To reach the cortex above, its fibres necessarily pass through the radiations of the corpus callosum, and thus, together with the corpus callosum, the fan-like bands of the two hemispheres form a capsule containing the thalami, the third ventricle, the caudate nuclei, and the anterior and central portions of the lateral ventricles. In sections, each internal capsule appears bent at an angle, the **genu,** which approaches the cavity of the lateral ventricle along the line of the boundary between the thalamus and the caudate nucleus. Along the genu runs the stria terminalis of the thalamus, and through the genu the capsule receives fibres from the internal medullary lamina of the thalamus, from the stratum zonale of the thalamus and from that of the caudate nucleus. At the genu each capsule is separable into two parts:—(1) the **frontal portion,** spreading between the caudate and lenticular nuclei; (2) the **occipital portion,** between the lenticular nucleus and the thalamus.

The corona radiata.—Above the corpus callosum, and in part joining its radia-

tions, the fibres of the internal capsule are dispersed to the cortex in all directions. The appearance known in coronal sections of the hemispheres as the corona radiata is produced both by the upper continuations of the internal capsule and by the radiations of the corpus callosum. The radiations derived from the internal capsule may be divided into a frontal, parietal, and occipital part, corresponding to the frontal, parietal, and occipital peduncles of the thalamus.

The radiation derived from the occipital portion of the internal capsule is subdivisible into—(1) an anterior part, passing between the lateral portion of the thalamus and the cortex directly above and the cortex of the temporal lobe, and (2) a posterior part, passing from the region of the lenticular nucleus backwards into the occipital lobe. The latter part accumulates into a well-defined band of fibres spread in the lateral wall of the posterior cornu of the lateral ventricle immediately outside the tapetum. This band consists, for the most part, of fibres arising in the pulvinar, the lateral geniculate body, and the superior quadrigeminate body, and is known as the **occipito-thalamic radiation,** or, more commonly, the **optic radiation,** since the fibres of which it is composed are chiefly concerned in the optic apparatus.

The external capsule is, as already noted, a thin sheet of white substance spread between the claustrum and the lenticular nucleus. It owes its appearance as such to the presence of the claustrum. It joins the internal capsule at the upper, posterior, and anterior borders of the putamen, and below the claustrum it is continuous with the general white substance of the temporal lobe. Thus it contributes to an encapsulation of the lenticular nucleus by white substance. Most of the fibres contained in it belong to the association system. Its projection fibres consist of those of the inferior peduncle of the thalamus, which pass from the under surface of the thalamus and, instead of continuing below to the cortex of the temporal lobe and insula, turn upwards, around the lenticular nucleus to the cortex above the insula.

The ascending projection fibres arise mostly from the cells of the nuclei of the thalamus and hypothalamic nucleus; some arise from nuclei in the mesencephalon and cerebellum. They may be summarised as follows:—

(1) *The terminal part of the general sensory pathway of the body.* The portion of the medial lemniscus which arises in the nuclei of the fasciculus gracilis and cuneatus terminates in the hypothalamic nucleus and the ventral portion of the lateral nucleus of the thalamus. The projection fibres given off by the latter nuclei pass chiefly through the anterior part of the occipital portion of the internal capsule and radiate to and terminate in the somæsthetic area of the cortex. Some few pass outside around the lenticular nucleus, and ascend by way of the external capsule.

(2) *The terminal part of the general sensory pathway of the head and neck.* The nuclei of termination of the sensory portions of the cranial nerves of the rhombencephalon (except the nuclei of the auditory nerve) give fibres which course upwards in the medial lemniscus (fillet) and reticular substance of the same and (chiefly) the opposite sides and terminate in the ventro-lateral portions of the thalamus and in the hypothalamic nucleus. Thence arise projection fibres which ascend to the somæsthetic area by practically the same route as those of the general sensory system for the body.

(3) *The terminal part of the auditory pathway.* The ventral and dorsal nuclei of termination of the cochlear nerve establish connections with the inferior quadrigeminate body, the medial geniculate body, and the nucleus of the lateral lemniscus. These nuclei send projection fibres through the anterior part of the occipital portion of the internal capsule, and thence by the temporal portion of the corona radiata to the cortex of the superior temporal gyrus (auditory area). Probably some of these fibres pass by way of the inferior peduncle of the thalamus. Some of the fibres arising in the nuclei of termination of the vestibular nerve convey impulses which reach the somæsthetic area, but the origin of the terminal portion of this system is uncertain.

(4) *The terminal part of the visual pathway.* The cells of the pulvinar, the lateral geniculate body, and the nucleus of the anterior quadrigeminate body, all serving as nuclei of termination of the optic tract, give off projection fibres which pass by way of the occipital portion of the internal capsule and the occipito-thalamic radiation to the cortex of the occipital lobe, chiefly the region about the posterior end of the calcarine fissure—the visual area.

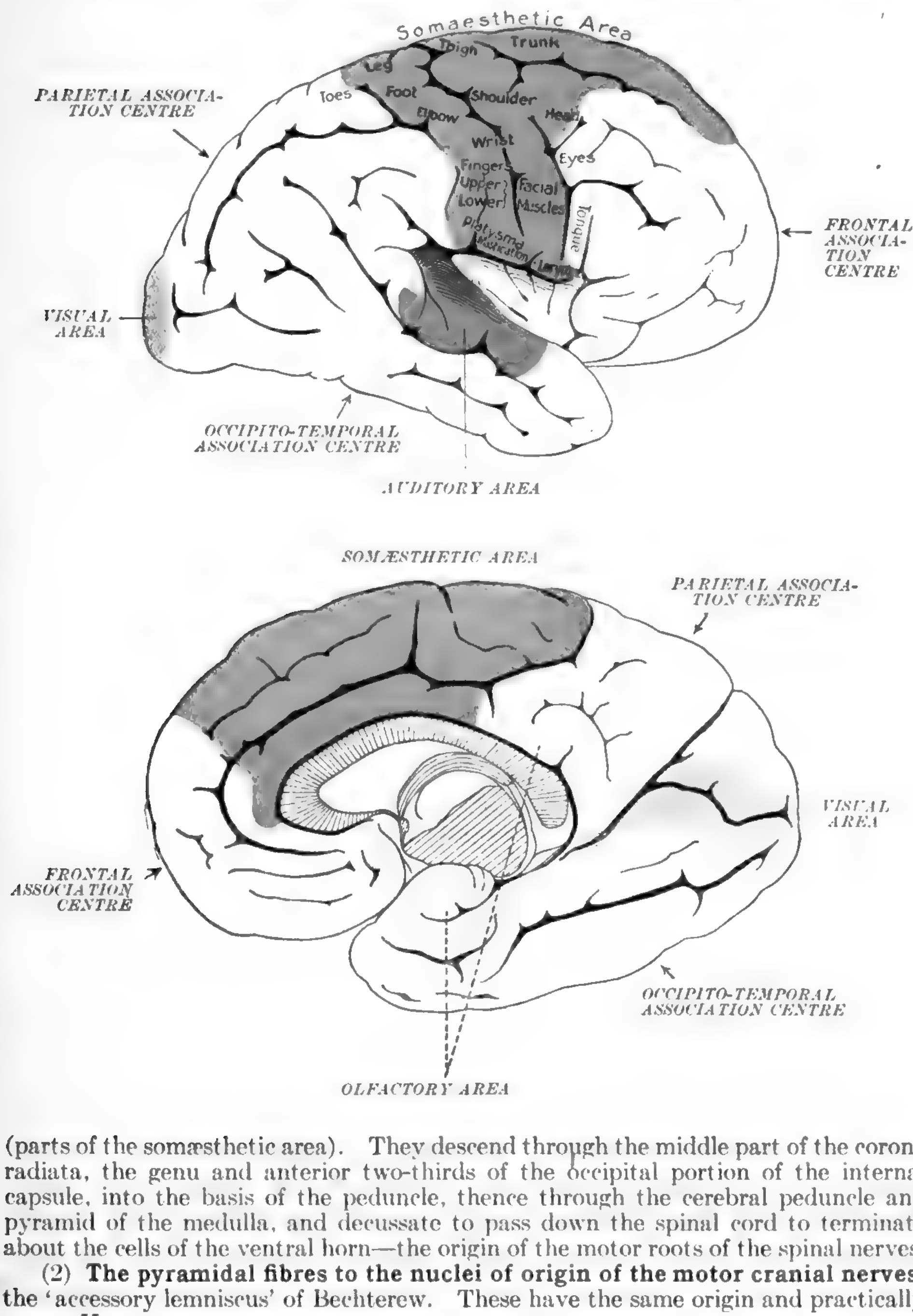
(5) *The terminal ascending cerebellar pathway.* The fibres of the brachium conjunctivum, after decussating, terminate both in the red nucleus and in the lateral nucleus of the thalamus. Some fibres from the red nucleus become projection fibres direct, others terminate in the medial and anterior portion of the lateral nucleus of

the thalamus. From the thalamus the projection fibres of this system pass in the general thalamo-cortical path to the somæsthetic area.

The descending projection fibres arise as outgrowths of the pyramidal cells of the respective regions of the cerebral cortex, in which the ascending fibres terminate. The principal groups of these are as follows:—

(1) **The pyramidal fasciculi.** The fibres of this group arise from the giant pyramidal cells of the posterior central gyri and anterior end of the paracentral lobule

FIG. 644.—DIAGRAMS SHOWING THE GENERAL SENSORY AND ASSOCIATION AREAS OF THE CONVEX AND MEDIAL SURFACES OF CEREBRAL HEMISPHERE. (From Spalteholz, after Flechsig.)



(parts of the somæsthetic area). They descend through the middle part of the corona radiata, the genu and anterior two-thirds of the occipital portion of the internal capsule, into the basis of the peduncle, thence through the cerebral peduncle and pyramid of the medulla, and decussate to pass down the spinal cord to terminate about the cells of the ventral horn—the origin of the motor roots of the spinal nerves.

(2) **The pyramidal fibres to the nuclei of origin of the motor cranial nerves,** the 'accessory lemniscus' of Bechterew. These have the same origin and practically

the same course as the pyramidal fibres to the spinal cord, save that they decussate shortly before their termination about the cells of the motor nuclei in the opposite side of the medulla. They have a definite position in the occipital portion of the internal capsule, viz., they course in its anterior portion, while the descending fibres for the arm muscles course in its middle and those for the leg in its posterior portion.

(3) **The frontal pontile path** (Arnold's bundle) arises in the cortex of the posterior portion of the frontal lobe, in front of the precentral gyrus, descends through the frontal part of the corona radiata and frontal portion of the internal capsule into the medial portion of the cerebral peduncle, and terminates in the nuclei of the pons.

(4) **The temporal pontile path** (Türk's bundle) arises in the cortex of the superior and middle temporal gyri, passes under the lenticular nucleus into the posterior part of the internal capsule, enters the cerebral peduncle lateral to its pyramidal portion, and terminates in the nuclei of the pons.

(5) **The occipito-mesencephalic path** (Flechsig's secondary optic radiation) arises in the cortex of the visual area of the occipital lobe (cuneus and about the calcarine fissure), passes forwards through the occipito-thalamic radiation, downwards in the posterior part of the occipital portion of the internal capsule, and terminates in the nucleus of the superior quadrigeminate body. It is probable that some of its fibres terminate directly in the nuclei of the eye-moving nerves.

(6) Those **fibres of the fornix** which arise in the hippocampus and terminate in the corpus mammillare or pass through it to the anterior nucleus of the thalamus of the same and opposite side (thalamo-mammillary fasciculus) or pass into the cerebral peduncle to the substantia nigra and probably to structures lower down (pedunculo-mammillary fasciculus).

The commissural system of fibres.—The commissural fibres of the telencephalon serve to connect or associate the functional activities of one hemisphere with those of the other. They consist of three groups:—

(1) The **corpus callosum**, the great commissure of the brain. A general description of this with the medial and lateral striæ running over it has already been given. It is a thick band of white substance, about 10 cm. wide, which crosses between the two hemispheres at the bottom of the longitudinal fissure. Its shape is such that in its medial transverse section its parts are given the names *splenium*, *body*, *genu*, and *rostrum* (figs. 615 and 726). Its under surface is medially joined to the fornix, in part by the septum pellucidum and in part directly. Laterally it is the tapetum of the roof of the lateral ventricle of either side. The majority of its fibres arise from the cortical cells of the two hemispheres, and terminate in the cortex of the side opposite that of their origin. In dissections, its fibres are seen to radiate towards all parts of the cortex—the radiation of the corpus callosum. Of these radiations, two strong bands curve backwards from the splenium into the occipital lobes, producing the figure known as the **forceps major.** Anteriorly, two similar but lesser bands curve from the genu forwards into the frontal lobe, producing the **forceps minor.**

(2) The **anterior commissure** has been described in connection with the rhinencephalon. In addition to the olfactory fibres coursing through it to and from the olfactory bulb of one hemisphere and the uncus of the opposite hemisphere, its greater part consists of fibres which arise in the cortex of the temporal lobe of one side and terminate in that of the opposite side. It crosses in the substance of the anterior boundary of the third ventricle, and through the ventral portions of the lenticular nuclei, and can be seen only in dissections (figs. 631 and 639). It is a relatively small, round bundle, and its mid-portion between its terminal radiations presents a somewhat twisted appearance.

(3) The **hippocampal commissure** belongs wholly to the limbic lobe (rhinencephalon), and has been described there. It connects the hippocampal gyri of the two sides, and crosses the mid-line under and usually adhering to the under surface of the splenium and to the beginning of the posterior pillars of the fornix (fig. 631).

The association system of the hemisphere.—The possibilities for association bundles connecting the different parts of the same hemisphere with each other are innumerable, and quite a number are recognised. They serve for the distribution or diffusion of impulses brought in from the exterior by the ascending projection system, and it is by means of them that the different areas of the cortex may function in harmony and coördination. Most of the association bundles are supposed to contain fibres coursing in both directions. Several of them have already been described in

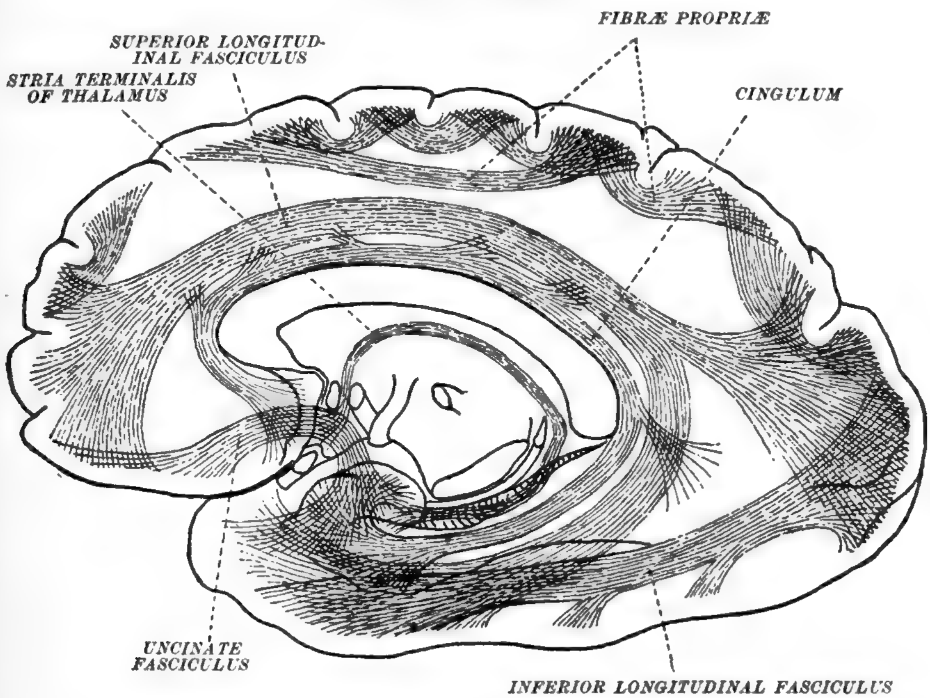
company with the grey masses with which they are concerned. They may be summarised as follows:—

(1) Those of short course, the **fibræ propriæ,** which associate contiguous gyri with each other. These loop around the bottoms of the sulci, continually receiving and losing fibres in the cortex they connect. The stripes of Baillarger within the cortical layer might be included among the short association bundles.

(2) The **cingulum** (girdle) lies in the gyrus cinguli and is shaped correspondingly. It extends from the anterior perforated substance and the subcallosal gyrus around the genu of the corpus callosum, then, under cover of the gyrus cinguli and around the splenium, and thence downwards and forwards in the hippocampal gyrus to the uncus. It is chiefly an aggregation of fibres of short course—fibres which associate neighbouring portions of the cortical substance beneath which they course, and which, by continually overlapping each other, form the bundle.

(3) The **uncinate fasciculus** is a hook-shaped bundle which connects the uncus and anterior portion of the temporal lobe with the basal portion of the frontal lobe,

Fig. 645.—Schematic Representation of Certain of the Association Pathways of the Cerebral Hemisphere.



i.e., the frontal pole with the orbital gyri. Its shape is due to its having to curve backwards around the stem of the lateral cerebral fissure.

(4) The **superior longitudinal fasciculus** is the longest of the association paths, and connects the frontal, occipital, and temporal lobes. From the frontal lobe it passes laterally, transverse to the radiations of the corpus callosum and the lower part of the corona radiata, along the inner aspect of the opercula, and above the insula to the region of the posterior end of the lateral fissure, and thence it curves downwards and forwards to the cortex of the temporal lobe. Some of its fibres extend to the cortex of the temporal pole. The occipital portion consists of a loose bundle given off from the region of the downward curve, which radiates thence to the occipital cortex.

(5) The **inferior longitudinal fasciculus** connects the temporal and occipital lobes and extends along the whole length of these lobes parallel with their tentorial surfaces. Posteriorly it courses lateral to the lower part of the occipito-thalamic radiation, from which it differs by the fact that its fibres are less compactly arranged.

(6) The medial and lateral **longitudinal striæ** of the upper surface of the corpus

callosum may be considered among the association pathways, since they extend between the grey substance of the hippocampus (dentate gyrus) and the subcallosal gyrus of the same hemisphere.

(7) Likewise the longitudinal fibres in the **stria terminalis of the thalamus** (tænia semicircularis) may be considered among the association pathways, since these connect the amygdaloid nucleus with the anterior perforated substance.

(8) The numerous fibres passing in both directions between the cerebral cortex and the nuclei of the corpus striatum belong to the association system. These do not form a definite bundle, but, instead, contribute appreciably to the corona radiata. However, a pathway described as the *occipito-frontal fasciculus* probably consists largely of the more sagittally running fibres of this nature. The existence of this fasciculus has been noted in degenerations and in cases of arrested development of the corpus callosum. Its fibres are described as contributing greatly to the tapetum, and as coursing immediately next to the ependyma of the lateral ventricle. As a mass, they appear in intimate connection with the caudate nucleus, and are spread towards both the frontal and the occipital lobes (chiefly the latter), in the mesial part of the corona radiata of those lobes.

(9) Since the olfactory bulb is a part of the hemisphere proper, the *olfactory tract* may be considered an association pathway connecting the olfactory bulb with the parolfactory area, the subcallosal gyrus, the anterior perforated substance, and the uncus. As already shown, a portion of the fibres of the tract belongs to the commissural system.

THE FUNCTIONAL AREAS OF THE CEREBRAL CORTEX

The known areas of specific function of the human cerebral cortex are relatively small (fig. 644). They comprise but little more than a third of the area of the entire hemisphere. They are—(1) the area of general sensibility or the somæsthetic area, and (2) the areas for the organs of special sense. They represent portions of the cortex in which terminate sensory or ascending projection fibres bearing impulses from the given peripheral structures, and in which arise motor or descending projection fibres bearing impulses in response.

Knowledge of the location of the areas has been obtained—(1) by the Flechsig method of investigation, and to a considerable extent by Flechsig himself; (2) from clinico-pathological observations, largely studies of the phenomena resulting from brain tumors and traumatic lesions; (3) by experimental excitation of the cortex of monkeys and apes, the resulting phenomena being correlated with the anatomical findings and compared with the observations upon the human brain. The remaining larger and less known areas of the cortex are referred to as 'association centres' or areas of the 'higher psychic activities.'

In development, the sensory fibres to the specific areas acquire their medullary sheaths first, before birth, and then the respective motor fibres from each become medullated. It is not till a month after birth that the association centres show medullation and therefore acquire active functional connection with the specific areas.

In defining an area it is not claimed that all the fibres bearing a given type of impulse terminate in that area, nor that all the motor fibres leading to the given reaction originate in the area. It can only be said that of the fibres concerned in a given group of reactions, more terminate and arise in the given area than in any other area of the cortex. The corresponding motor fibres arise both in the region of the termination of the sensory fibres (sensory area) and also in a zone (motor area) either partially surrounding or bordering upon a part of the region of termination.

The different areas are as follows:—

(1) The **somæsthetic (sensory-motor) area,** the area of general sensibility, and the area in which arise the larger part of the cerebral motor or pyramidal fibres for the cortical control of the general muscular system. As is to be expected, it is the largest of the specific areas. It includes the anterior central gyrus, posterior central gyrus, the posterior ends of the superior, middle, and inferior frontal gyri, the paracentral lobules, and the upper portion of the adjacent part of the gyrus cinguli. The ascending or sensory fibres are said to terminate most abundantly in the part posterior to the central sulcus (Rolandi), the posterior central gyrus being the special area of cutaneous sensibility, and the adjacent anterior ends of the horizontal parietal gyri have been designated as the area of 'muscular sense.' Both these areas are carried over upon the medial surface to involve the lower part of the paracentral lobule and a part of the gyrus cinguli. The anterior central gyrus gives origin to relatively more motor fibres than the other portions of the somæsthetic area. In distribution, the muscles furthest away from the cortex are innervated from the most superior part of the area, the leg area being in the supero-mesial border of the hemisphere, while that from the head is in the anterior and inferior part of the area (fig. 644). The muscles of mastication and the laryngeal muscles are controlled from the fronto-parietal operculum. Broca's convolution of the left side constitutes the especial area of speech, and Mills has extended this area to include the supero-anterior portion of the insula below.

(2) **The visual area.**—The especial sensory portion of this area is that immediately bordering upon either side of the posterior part of the calcarine fissure. The entire area, motor and sensory overlapping each other, includes the whole of the cuneus. The motor visual area proper is described as the more peripheral portion of the entire area. In addition, there is a small area producing eye movements situated in the posterior end of the middle frontal gyrus—an anterior extension of the somæsthetic area.

(3) **The auditory (cochlear) area** comprises the middle third of the superior temporal gyrus and the transverse temporal gyri of the temporal operculum. The motor portion of this area lies in its inferior border. The fibres arising in the area course outwards in the temporal pontile path to the motor nuclei of the medulla.

(4) **The olfactory area** consists of the olfactory trigone, the parolfactory area, the subcallosal gyrus, part of the anterior perforated substance, the hippocampus (especially the uncus), and the callosal half of the gyrus cinguli. Its motor or efferent area lies chiefly in the hippocampal gyrus, the fibres from which pass out from the telencephalon by way of the fornix.

(5) **The gustatory area** comprises the anterior portion of the fusiform gyrus and the zone (motor portion) about the anterior extremity of the inferior temporal sulcus.

(6) **The association centres.**—The relatively large areas allotted at present to the so-called higher psychic activities are indicated in fig. 644. The great relative extent of these is one of the characteristics of the human brain. They probably merely represent the portions of the cortex of which little is known, and may eventually be subdivided into more specific areas. They are considered to be connected with the structures below by fewer projection fibres than are the recognised sense areas named above, while, on the other hand, they are rich in association fibres. By means of the latter they are in intimate connection with the specific areas and have abundant means of exercising a controlling influence upon the functions of these areas. According to Flechsig, they consist of—(1) a *parietal association centre*, comprising that part of the parietal cortex between the somæsthetic area and the visual area; (2) an *occipito-temporal association centre*, including the unspecified portions of the temporal lobe and the adjoining portion of the occipital lobe not included in the visual area: (3) a *frontal association centre*, including all the frontal lobe anterior to the somæsthetic and olfactory areas. In the folds of the inferior parietal lobule of the parietal association centre such intellectual activities as the optic discrimination of words, letters, numbers, and objects generally are supposed to take place, while the superior parietal lobule is the general region for the perception of form and solidity of objects—the stereognostic centre. To a portion of the middle temporal gyrus has been attributed the faculty of the auditory discrimination of words and sounds and the association of objects with their names.

GENERAL SUMMARY OF SOME OF THE PRINCIPAL CONDUCTION PATHS OF THE NERVOUS SYSTEM

In the following summary the arabic numerals indicate paragraphs in which are mentioned the nuclei or ganglia containing the cell-bodies of the neurones interposed in the chains; the small letters indicate the different names given to the different levels of the pathways through which their fibres run. For detailed descriptions of either nuclei or pathways see pages describing them. Only the more common connections are mentioned here.

I. The Cerebro-spinal Path

A. *The ascending system of neurones.*

1. Spinal ganglion—neurone of first order.
   (*a*) Terminal corpuscles and peripheral process of T-fibre.
   (*b*) Dorsal or afferent root of spinal nerve.
   (*c*) Ascending branch of bifurcation of dorsal root fibre in fasciculus gracilis, or fasciculus cuneatus of spinal cord.
2. Nucleus of fasciculus gracilis or nucleus of fasciculus cuneatus in medulla oblongata—neurone of second order.
   (*a*) Internal arcuate fibres.
   (*b*) Decussation of lemniscus.
   (*c*) Interolivary stratum of lemniscus of opposite side.
   (*d*) Medial lemniscus.
3. Hypothalamic nucleus and lateral nucleus of thalamus—neurone of third order.
   (*a*) Internal capsule, anterior part of its occipital portion.
   (*b*) Corona radiata, fronto-parietal part.
   (*c*) Somæsthetic area of cerebral cortex.

B. *Descending system of neurones* (fig. 647).

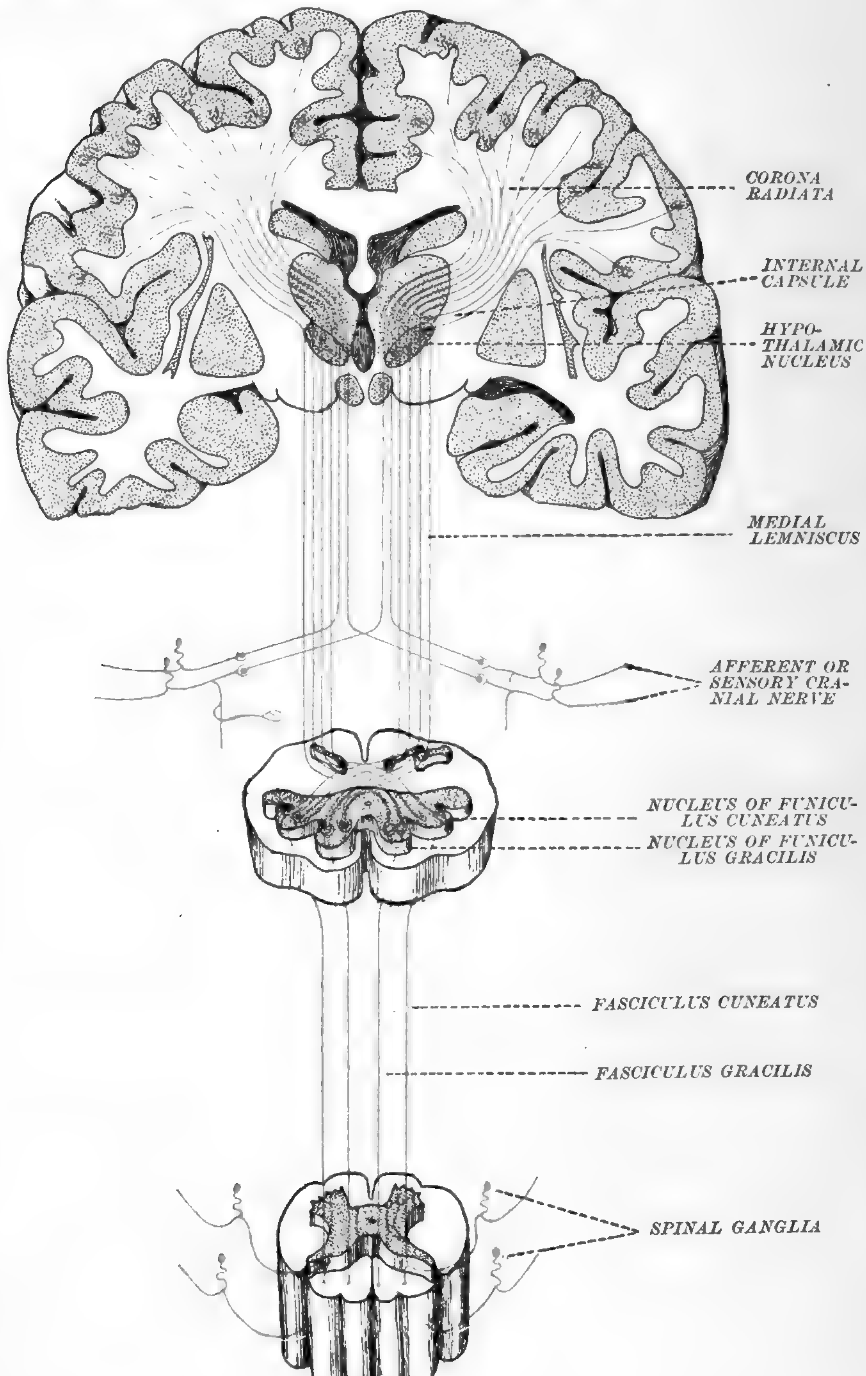
1. Giant pyramidal cells of somæsthetic area.
   (*a*) Corona radiata, fronto-occipital part.
   (*b*) Internal capsule, genu and anterior part of occipital portion.
   (*c*) Basis of the cerebral peduncle and the peduncle.
   (*d*) Pyramid of medulla oblongata.
   (e^1) Decussation of pyramids.
   (f^1) Lateral cerebro-spinal fasciculus (crossed pyramidal tract).
   (e^2) Ventral cerebro-spinal fasciculus (direct or uncrossed pyramidal tract).
   (f^2) Gradual decussation of latter in cervical and upper thoracic regions of spinal cord.
2. Cells of ventral horn of spinal cord of opposite side.
   (*a*) Ventral or efferent roots of spinal nerves.
   (*b*) Peripheral nerve-trunks directly to muscles or indirectly by way of sympathetic neurones.

II. Short 'Reflex' Paths of Spinal Cord

1. Spinal ganglia.
   (*a*) Terminal corpuscles and peripheral process of T-fibre.
   (*b*) Dorsal root of spinal nerve.

(*c*) Collaterals and descending branches of bifurcation of dorsal root fibres in spinal cord.
(*d*) Directly to ventral horn cells of same level of spinal cord.
(*e*) Or to same through intermediation of Golgi cell of type II.
(*f*) Or to neurones of fasciculi proprii to ventral horn cells of other levels of spinal cord.

Fig. 646.—Scheme of Ascending Cerebro-spinal Conduction Pathways.



2. Ventral horn cells of same and opposite side and thence by way of ventral roots and peripheral nerve trunks directly to muscles or indirectly through sympathetic.

III. Cerebral Path for the Cranial Nerves Exclusive of Those of Special Sense

A. *Ascending system of neurones.*
1. Ganglia of origin of sensory components of vagus, glossopharyngeus, pars intermedia of facial, and trigeminus.
   (a) Peripheral arborisations and afferent peripheral branches of T-fibres of same.
   (b) Central branches of T-fibres of same.
2. Nuclei of termination of central branches (bifurcated and unbifurcated) in medulla oblongata.
   (a) Reticular formation and medial lemniscus of same and (chiefly) the opposite side.
3. Hypothalamic nucleus and lateral nucleus of thalamus.
   (a) Internal capsule, anterior part of occipital portion.
   (b) Corona radiata, fronto-parietal part.
   (c) Somæsthetic area of cortex cerebri.

B. *Descending system of neurones.*
1. Pyramidal cells of somæsthetic area.
   (a) Corona radiata, fronto-parietal.
   (b) Internal capsule, genu chiefly.
   (c) Basis of cerebral peduncle and peduncle.
   (d) Accessory lemniscus of von Bechterew.
2. Nuclei of origin of motor cranial nerves and motor components of mixed cranial nerves, and thence by way of these nerves to the respective muscles supplied.

IV. The Short 'Reflex' Paths of the Cranial Nerves

These consist of the central branches of their afferent or sensory fibres, terminating in the nuclei of origin of both their own motor components and in the nuclei of origin of other motor nerves. Fibres to the more distant nuclei pass to them by way of the medial longitudinal fasciculus. Instead of terminating in the motor nuclei directly, the sensory fibres are frequently interrupted by a third or intermediate neurone interposed in the chain. The vagus and glosso-pharyngeus are connected by way of the solitary fasciculus and its nucleus with the structures below their level of entrance, probably even with the ventral horn cells of the upper segments of the cervical cord, and through these with the muscles of respiration.

V. Conduction Paths Involving the Cerebellum

A. *Ascending cerebellar pathways.*
1. Spinal ganglia.
   (a) Dorsal roots of spinal nerves.
   (b) Collaterals and descending branches of bifurcation of dorsal root fibres in spinal cord.

2x. Dorsal nucleus (Clarke's column).
   (a) Cerebello-spinal fasciculus (direct cerebellar tract).
   (b) Restiform body (inferior cerebellar peduncle)—
   (c) Joined in medulla by external arcuate fibres (crossed and uncrossed fibres arising in nuclei of funiculus gracilis and cuneatus);
   (d) Joined in medulla by fibres arising in nuclei of termination of afferent vagus, glosso-pharyngeal, vestibular, and trigeminal nerves;
   (e) Joined by fibres both to and from (ascending and descending) the inferior olivary nucleus of the same and opposite sides (*cerebello-olivary fibres*).

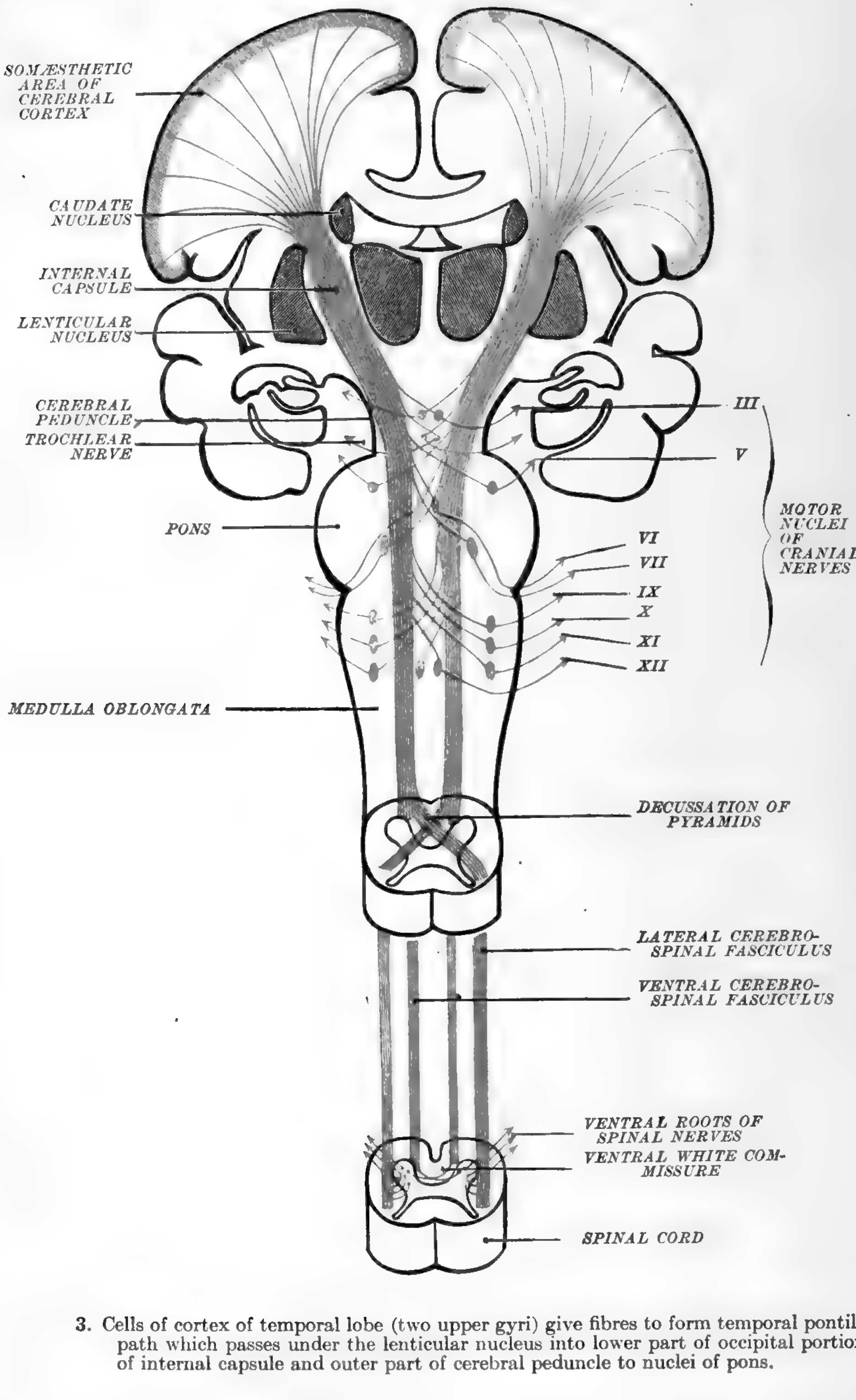
2y. Nerve-cells in base of ventral horn of same and opposite side.
   (a) Antero-lateral cerebello-spinal fasciculus (Gowers' tract), ascending through spinal cord and reticular formation of medulla and pons.
   (b) Anterior medullary velum and brachium conjunctivum to cerebellar cortex (vermis) (fig. 606).

3. Cerebellar cortex (vermis), dentate nucleus, nucleus fastigii, nucleus emboliformis, and nucleus globosus.
   (a) White substance (corpus medullare) of cerebellum, associating various regions of its cortex and its nuclei with each other.
   (b) Brachium conjunctivum (superior cerebellar peduncle) arising chiefly from dentate nucleus and cortex vermis.
   (c) Decussation of brachium conjunctivum.
4. Red nucleus and ventral portion of lateral nucleus of thalamus. Some fibres of the brachium conjunctivum terminate in the red nucleus; many merely give off collaterals to it in passing to their termination in the thalamus. Most of the ascending fibres arising in the red nucleus also terminate in the ventral part of the thalamus.
   (a) Internal capsule, middle third, and fronto-parietal part of corona radiata.
   (b) Somæsthetic area of cerebral cortex and probably cortex of frontal lobe anterior to it.
   (c) Inferior peduncle of thalamus to cortex of temporal lobe.

B. *Descending cerebro-cerebellar paths.*
1. Pyramidal cells of somæsthetic area send fibres through corona radiata, internal capsule, and cerebral peduncle to nuclei of pons and arcuate nucleus of same and opposite side.

2. Cells of cortex of posterior part of frontal lobe give fibres to form frontal pontile path through frontal parts of corona radiata and internal capsule and through medial part of cerebral peduncle to nuclei of pons.

Fig. 647.—Scheme of Descending Cerebro-spinal Conduction Pathways.



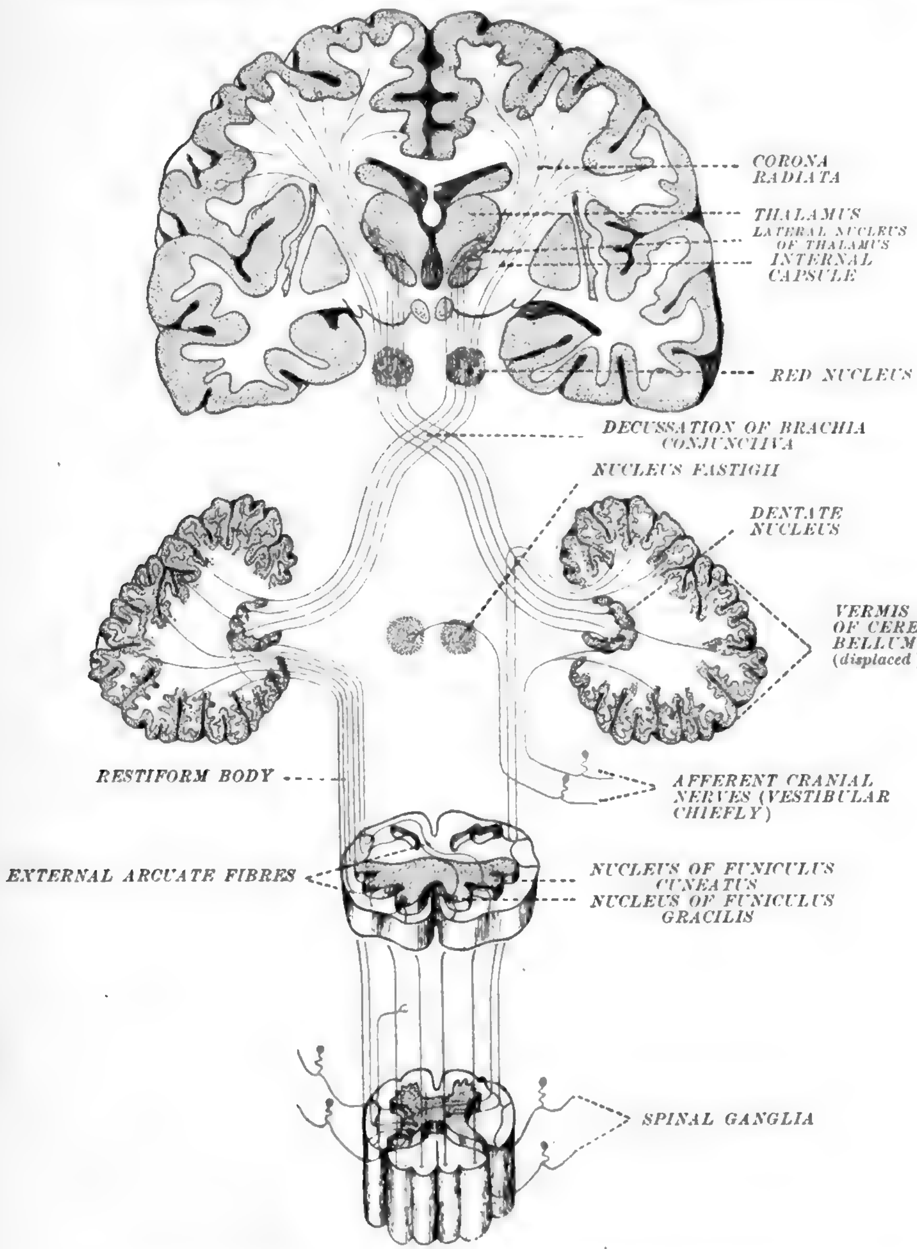
3. Cells of cortex of temporal lobe (two upper gyri) give fibres to form temporal pontile path which passes under the lenticular nucleus into lower part of occipital portion of internal capsule and outer part of cerebral peduncle to nuclei of pons.

4. Cells of nuclei of pons send fibres by way of brachium pontis (middle cerebellar peduncle) to cortex of cerebellar hemisphere, probably of opposite side to that of the origin of the cerebral fibres connecting with the cells (fig. 606).

C. Descending cerebello-spinal paths.

1. From cells of nucleus fastigii and probably from other nuclei and from cortex of cerebellum, of same and opposite sides, into anterior marginal fasciculus of spinal cord (fig. 571), and thence to the cells of the anterior horn.

Fig. 648.—Scheme of Principal Ascending Cerebellar Conduction Paths.



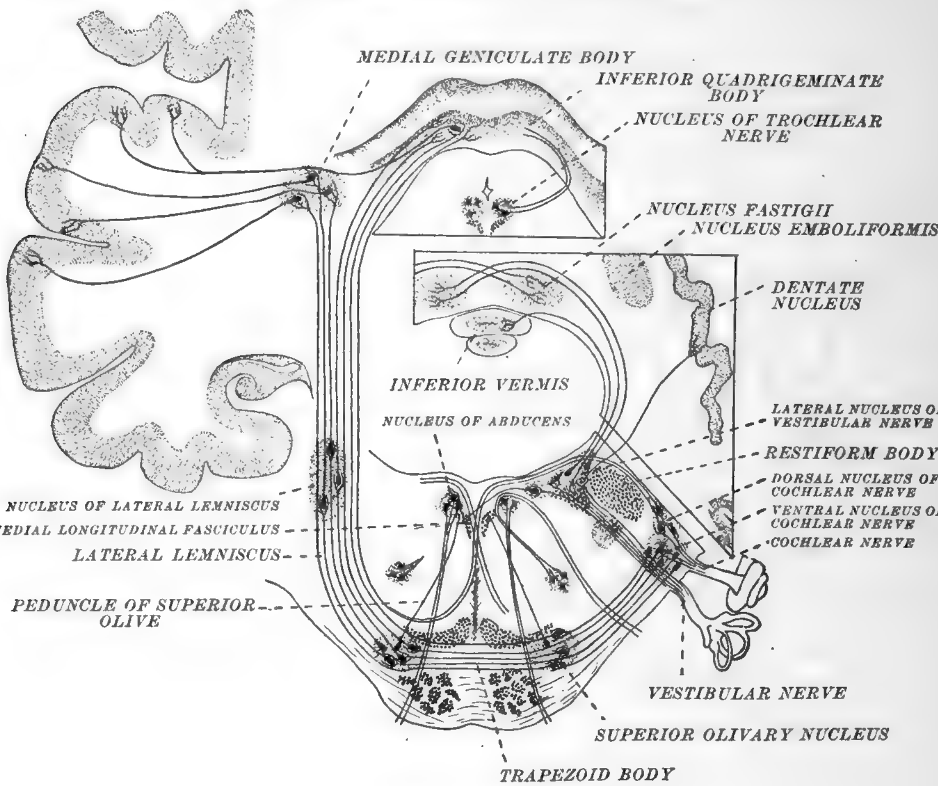
2. Probably connected with the cerebellum is the pathway arising in the red nucleus of the opposite side and from the lateral vestibular nucleus (Deiters' nucleus) of the same side and descending in the intermediate bundle of the lateral funiculus of the spinal cord (fig. 571). The part from the red nucleus (rubro-spinal tract) decussates in the ventral portion of the tegmentum of the mesencephalon and passes through the medulla oblongata in the medial longitudinal fasciculus, while that from Deiters' nucleus traverses the medulla in the reticular formation.

VI. The Auditory Conduction Paths

A. Vestibular division (vestibular nerve).

1. Vestibular ganglion gives origin to the peripheral utricular and three ampullar branches and to the combined and centrally directed vestibular nerve.
2. Lateral vestibular nucleus (Deiters'), medial nucleus, superior nucleus, and nucleus of descending vestibular root (nuclei of termination) give origin to fibres as follows:—
   (*a*) From lateral and superior nuclei to nucleus fastigii of opposite side and to cortex of vermis and to dentate nucleus (cerebellar connection).
   (*b*) From medial and superior nuclei to nuclei of origin of eye-muscle nerves of same and opposite sides, by way of medial longitudinal fasciculi.
   (*c*) From lateral nucleus and nucleus of descending root through reticular formation into lateral funiculus of spinal cord.
   (*d*) It is probable that all the nuclei of termination give off fibres bearing ascending impulses which ultimately reach the somæsthetic area, but the course pursued and neurones involved in such a chain are uncertain.

Fig. 649.—Diagram Showing Some of the Connections of the Acoustic Nerve.



B. Cochlear division (cochlear nerve).

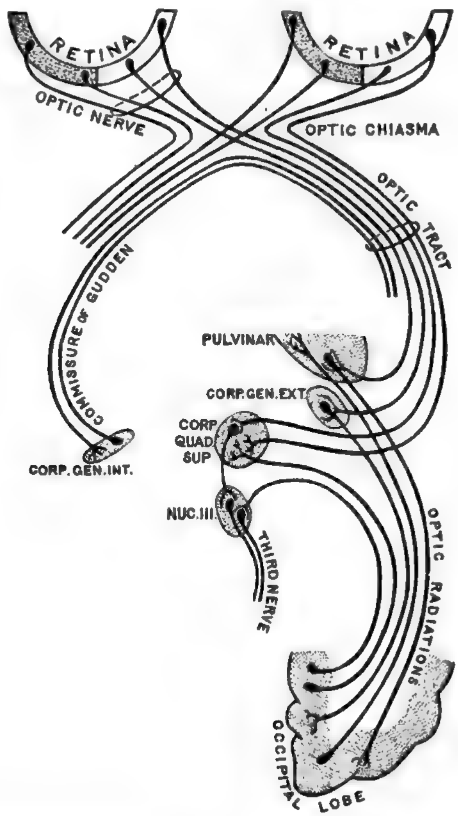
1. Spiral ganglion of the cochlea gives origin to short peripheral fibres to organ of Corti, and to the centrally directed cochlear nerve.
2. Dorsal and ventral nuclei of the cochlear nerve (nuclei of termination).
   (*a*) Striæ medullares arise from dorsal nucleus and pass around outer side of restiform body (acoustic tubercle), then medianwards under ependyma of floor of fourth ventricle to mid-line, then ventralwards into tegmentum, where it decussates and joins trapezoid body to lateral lemniscus of opposite side.
   (*b*) Fibres arising in ventral nucleus pass ventrally medianwards and some terminate in the superior olivary nucleus of same side; others pass by way of trapezoid body and lateral lemniscus to terminate in superior olivary nucleus, nucleus of lateral lemniscus, medial geniculate body and nucleus of inferior quadrigeminate body of the opposite side.
3. Nuclei of superior olives of both sides and nucleus of lateral lemniscus send fibres by way of lateral lemniscus to inferior quadrigeminate body and through inferior brachium to medial geniculate body, and some may pass uninterrupted, even to the cortex of the temporal lobe.

4. Fibres from medial geniculate body and nucleus of inferior quadrigeminate body pass into internal capsule and through temporal part of corona radiata to middle third of superior temporal gyrus and adjacent portions (auditory area).
5. From superior olivary nucleus arise fibres which terminate in nucleus of abducens or pass by way of the medial longitudinal fasciculus to other motor nuclei of cranial nerves (peduncle of superior olive). It is probable that fibres from the auditory area of the cerebral cortex are also distributed to nuclei of the cranial nerves.

VII. Conduction Paths of the Optic Apparatus

1. 'Bipolar' cells of retina with short (peripheral) processes to layer of rods and cones (neuro-epithelium) and short centrally directed processes to ganglion-cell layer of retina (nucleus of termination).

Fig. 650.—Diagram of Principal Pathways of Optic Apparatus. (After Cunningham.)



2. Ganglion-cells of retina give origin to—
   (*a*) Optic stratum of retina.
   (*b*) Optic nerve.
   (*c*) Optic chiasma; fibres from nasal side of retina cross in chiasma to opposite side; fibres from lateral side of retina continue on same side in—
   (*d*) Optic tract to—
3. Pulvinar of thalamus, lateral geniculate body, and nucleus of superior quadrigeminate bodies.
   (*a*) Fibres from nucleus of superior quadrigeminate bodies pass ventrally to medial longitudinal fasciculus of same and opposite sides, and from it are distributed to nuclei of origin of eye-muscle nerves.
   (*b*) Fibres from lateral geniculate body and pulvinar pass through occipital portion of internal capsule and occipito-thalamic radiation (optic radiation) to cortex of occipital lobe (visual area).
4. Cells of visual area of cortex send fibres through occipito-thalamic radiation and internal capsule to nucleus of superior quadrigeminate bodies (occipito-mesencephalic fasciculus), and thence, probably interrupted by cells of this nucleus, to nuclei of eye-muscle nerves.
5. Cells of nucleus of superior quadrigeminate body and pulvinar send fibres by way of medial longitudinal fasciculus into lateral and ventral funiculi of spinal cord (see fig. 571), chiefly of the opposite side. Fibres from the quadrigeminate body cross mid-line in decussation of 'optic-acoustic reflex path' (fig. 611).

VIII. Conduction Paths of Olfactory Apparatus

1. Bipolar cells of olfactory region of nasal epithelium send short (peripheral) processes towards surface of nasal cavity and centrally directed processes, the olfactory nerve, through lamina cribrosa of ethmoid bone into olfactory bulb (glomerular layer).
2. 'Mitral cells' of olfactory bulb give fibres which form—
   (a) The olfactory tract which divides into—
   (b) Medial olfactory stria through which fibres pass—(1) into parolfactory area (Broca's area); (2) into subcallosal gyrus; and (3) by way of anterior cerebral commissure to olfactory bulb of opposite side.
   (c) Intermediate olfactory stria to anterior perforated substance.
   (d) Lateral olfactory stria, which terminates to some extent in anterior perforated substance, but chiefly in uncus, hippocampal gyrus, and gyrus cinguli (olfactory area).
3. Cells of uncus and hippocampal gyrus give fibres which form—
   (a) The cingulum (in part), by which they are associated with the cortex of the gyrus cinguli, the subcallosal gyrus, and the anterior perforated substance.
   (b) The hippocampal commissure (in part), by which they are connected with the grey substance of the opposite side.
   (c) The fornix, which, interrupted in part in the nuclei of the corpus mammillare, conveys impulses—(1) to the anterior nucleus of thalamus of the same and opposite sides (thalamo-mammillary fasciculus), and (2) into the cerebral peduncle and substantia nigra (pedunculo-mammillary fasciculus), and by way of this peduncle probably to the nuclei of the mesencephalon and medulla oblongata.

The Relations of the Brain to the Walls of the Cranial Cavity

The precise methods by which the exact positions of the most important fissures, sulci, gyri, and areas can be ascertained and mapped out on the surface of the head in the living subject are fully described in Section XIII. Here, only a very general survey of the relations of the brain to the cranial bones is given and from a purely anatomical standpoint.

The parts of the brain which lie in closest relation with the walls of the cranial cavity are the olfactory bulb and tract, the basal and lateral surfaces of the cerebral hemispheres, the inferior surfaces of the lateral lobes of the cerebellum, the ventral surfaces of the medulla and pons, and the hypophysis.

Certain of these portions of the brain lie in relation with the basi-cranial axis, that is, with the basi-occipital, the basi-sphenoid, and the ethmoid bones, while others are associated with the sides and vault of the cranial cavity. Considering the former portions first, the ventral surface of the medulla oblongata, which is formed by the pyramids, lies upon the upper surface of the basi-occipital bone. More superiorly the ventral surface of the pons rests upon the basi-sphenoid, from which it is partly separated by the basilar artery and the sixth pair of cranial nerves. In front of the dorsum sellæ the hypophysis (pituitary body) is lodged in the pituitary fossa. Still further forwards the olfactory tracts lie in grooves on the upper surface of the pre-sphenoid section of the sphenoid bone; and in front of the sphenoid the olfactory bulbs rest upon the cribriform plates of the ethmoid.

Behind and lateral to the posterior part of the foramen magnum the lateral lobes of the cerebellum are in relation with the cranial wall, resting upon the lower parts of the supra-occipital and the posterior parts of the ex-occipital portions of the occipital bone, while anteriorly each lobe is in relation with the inner surface of the mastoid process and the posterior surface of the petrous portion of the temporal bone. The area of the skull wall which is in close relationship with the cerebellar hemispheres may be indicated, on the external surface of the skull, by a line which commences at the lower part of the external occipital protuberance and thence runs upwards and outwards. It crosses the superior curved line a little beyond its centre, and, continuing in the same direction, crosses the lower part of the lambdoid suture and reaches a point directly above the asterion (the meeting-point of the occipital, temporal, and parietal bones); thence it descends, just in front of the occipito-mastoid suture, to the tip of the mastoid process, and there turns inwards to its termination at the margin of the foramen magnum, immediately behind the posterior end of the occipital condyle.

The basal surface of each cerebral hemisphere may be said to consist of two parts, an anterior and a posterior, separated by the stem of the lateral fissure. The anterior part, formed by the orbital surface of the frontal lobe, rests upon the upper surfaces of the orbital plate of the frontal bone and the lesser wing of the sphenoid. It is, therefore, in close relation with the upper wall of the orbital cavity. The posterior part, behind the stem of the lateral fissure, is formed by the anterior portion of the temporal lobe, including its apex. The apex itself projects against the orbital plate of the great wing of the sphenoid bone, and it is in relationship with the posterior part of the outer wall of the orbit. The basal surface of the hemisphere, behind the apex of the temporal lobe, is in contact with the upper surfaces of the great wing of the sphenoid and the petrous part of the temporal bone.

The convex surfaces of the cerebral hemispheres have the most extensive relationships with the cranial wall, and it is more especially to these surfaces that the practical surgeon turns his attention. The general area in which the convex surface of each cerebral hemisphere is in relation with the skull bones is readily indicated by a series of lines which correspond with the positions of its superciliary, infero-lateral, and supero-mesial borders.

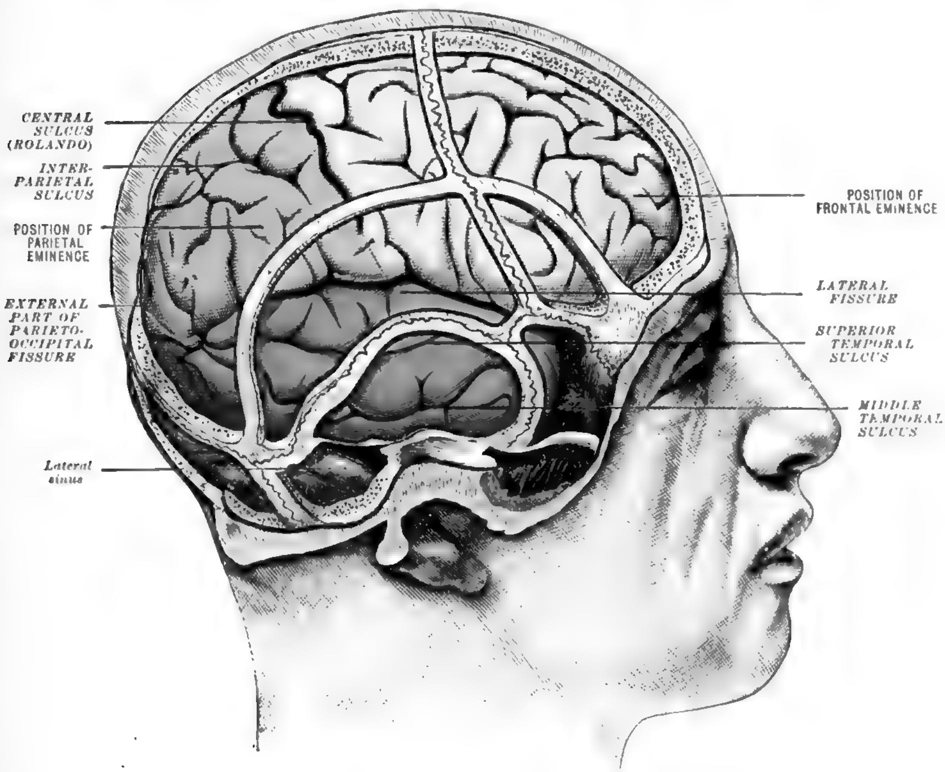
The line marking the superciliary margin of the hemisphere commences at the nasion (the mid-point of the fronto-nasal suture); it passes outwards above the superciliary ridge, crosses the temporal ridge, then, turning backwards in the temporal fossa, it reaches the parieto-sphenoidal suture, and continues backwards along it to its posterior extremity.

The line marking out the infero-lateral border commences at the posterior end of the parieto-sphenoidal suture, whence it passes downwards, in front of the spheno-squamous suture, to the infra-temporal crest (pterygoid ridge); there it turns backwards and, running parallel with and internal to the zygomatic arch, it crosses the root of the zygoma, and, ascending slightly, it passes above the external auditory meatus. Continuing backwards with an inclination upwards it reaches a point immediately above the asterion; thence it descends, and, crossing the lower part of the lambdoid suture and the superior curved line, it passes inwards to the lower part of the external occipital protuberance.

The supero-mesial border of the hemisphere is defined by a line which runs from the nasion to the inion. This line should be drawn about 5 mm. to the outer side of the sagittal suture, because the mesial area is occupied by the superior sagittal sinus, and it should be further away from the middle line on the right than on the left side, because the sinus tends to lie more to the right side.

The area of the skull wall enclosed by the three lines which mark the positions of the superciliary, infero-lateral, and the supero-mesial borders of the cerebral hemisphere is formed by the vertical plate of the frontal bone, the parietal bone, the great wing of the sphenoid, the squamous

Fig. 651.—Drawing of a Cast of the Head of an Adult Male.
(Prepared by Professor Cunningham to illustrate cranio-cerebral topography.)



part of the temporal, and the upper section of the supra-occipital segment of the occipital bone. It covers the outer surfaces of the frontal, parietal, temporal, and occipital lobes and the fissures and sulci which bound and mark them.

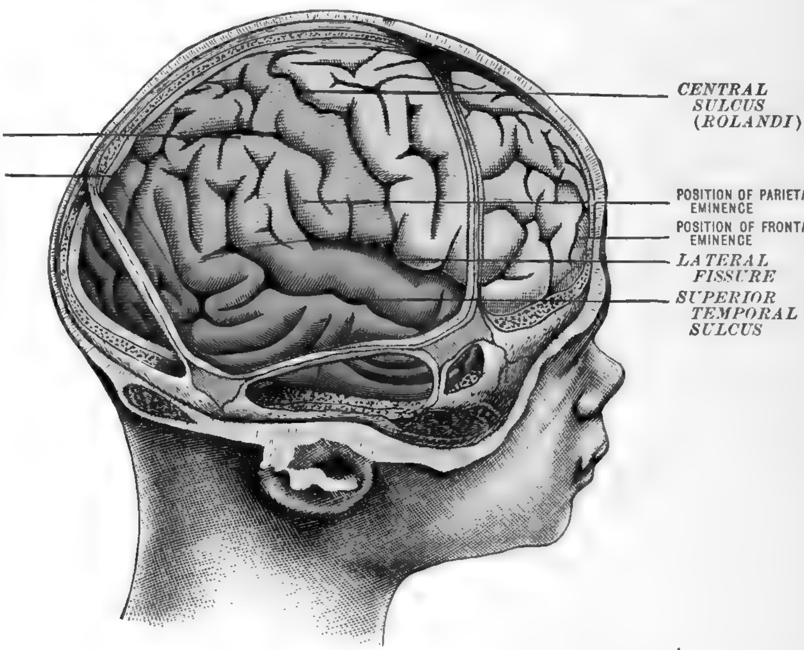
In every consideration of the topographical relations of the cerebral gyri to the walls of the cranial cavity it must be borne in mind that the conditions are not constant, and that, therefore, the relations are variable. The three main factors upon which this variability depends are age, sex, and the shape of the skull. As examples of the variations which occur it may be mentioned that the lateral fissure is higher in the child than in the adult (compare figs. 651 and 652). The upper end of the central sulcus is further away from the coronal suture in the female and in the child than in the adult male, and in dolichocephalic than in brachycephalic heads. The angle formed between the line of the central fissure and the mid-sagittal plane, which averages about 68° in the adult, is more acute in dolichocephalic heads, and the external part of the parieto-occipital fissure is further forwards in the child, and possibly in the female, than it is in the adult male.

The position of the posterior horizontal limb of the lateral fissure varies even in the adult. Its posterior part is always under cover of the parietal bone, and it terminates either in front of or below the parietal eminence, but the anterior part may be above, parallel with, or below the squamo-parietal suture. In the adult the anterior part of the fissure runs upwards and backwards

from the posterior end of the spheno-parietal suture along the anterior part of the squamo-parietal suture to its highest point; thence it continues in the same direction beneath the parietal bone towards the lambda, terminating either in front of or below the parietal eminence. In the child, however, the fissure is considerably above the line of the squamo-parietal suture (fig. 652), which it gradually approaches, attaining its adult position about the ninth year. This change of position, which occurs during the first nine years, is due partly to the ascent of the sutural line and partly to the descent of the fissure on the surface of the brain.

The frontal bone always covers the superior, middle, and inferior frontal gyri, except their posterior extremities, which are beneath the parietal bone (fig. 651). The ascending limb (ramus anterior ascendens) of the lateral fissure, which cuts into the posterior part of the inferior frontal gyrus, runs parallel with and under cover of the lower part of the coronal suture, or immediately in front of it, and the anterior horizontal limb is parallel with and beneath the upper margin of the great wing of the sphenoid. The parietal bone is in relation with the convex surfaces of four lobes of the brain. Speaking very generally, it may be said that the anterior third covers the posterior part of the frontal lobe, including the anterior central gyrus, and the posterior ends of the superior, middle, and inferior frontal gyri and the precentral sulcus. The posterior two-thirds are superficial to the parietal lobe, the posterior part of the temporal lobe, the anterior part of the occipital lobe, the posterior part of the horizontal limb of the lateral fissure, the upper and lower parts of the post-central sulcus, the interparietal sulcus, the posterior sections of the superior and middle temporal sulci, and the external part of the parieto-occipital fissure. The

Fig. 652.—Drawing of a Cast of the Head of a Newly Born Male Infant. (Prepared by Professor Cunningham to illustrate cranio-cerebral topography.)



central sulcus is beneath the parietal bone at the junction of its middle and anterior thirds (fig. 651).

In the adult, the upper end of the central sulcus lies 55 per cent. of the whole length of the naso-inionic line behind the nasion. It is 55 mm. from the coronal suture in dolichocephalic, and 54·4 mm. in brachycephalic, heads. The lower end of the sulcus, which is immediately above the posterior horizontal limb of the lateral fissure, lies beneath the point of intersection of the auriculo-bregmatic line with a line drawn from the stephanion (the point where the temporal ridge cuts the coronal suture) to the asterion. In skulls of a sagittal length of 18 cm. and over, this point is 45·5 per cent. of the horizontal arc from the glabella to the inion, and in skulls of less than 18 cm. it is 46 per cent. of the same arc posterior to the glabella.

The upper end of the parieto-occipital fissure usually lies about 5 mm. in front of the lambda, and the course of the fissure may be indicated by a line drawn from 5 mm. in front of the lambda to a point immediately above the asterion, and, as the latter point corresponds with the pre-occipital notch on the infero-lateral border of the hemisphere, the line in question will indicate the adjacent margins of the parietal, temporal, and occipital lobes.

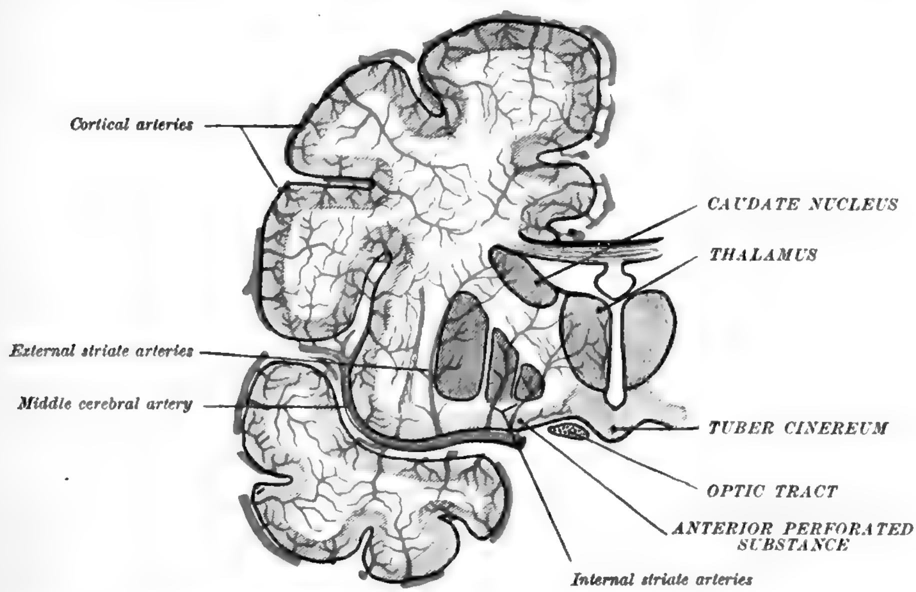
The occipital bone is in close relation with the cerebellum, as already pointed out, but it also covers the posterior part of the outer surface of the occipital lobe of the cerebral hemisphere. The great wing of the sphenoid covers the outer surface of the apex of the temporal lobe, and the squamous part of the temporal bone covers the anterior parts of the superior, middle, and inferior temporal gyri and the sulci which separate them.

The Blood Supply of the Encephalon

The double origin of the continuous arterial system of the brain given by the confluence of the two ventral arteries and by the two internal carotid arteries, together with the description of the general distribution of the different cerebral, mesencephalic, and cerebellar arteries into which the system is divided, and the origin and course of the corresponding veins, are fully dealt with in Section V. Here attention may be called briefly to the abundant and systematic internal distribution of the terminal branches of the system and their intimate arrangement for the actual nourishment of the nervous tissues within.

The general plan of the blood supply for the entire encephalon may be summarised as follows: —(1) At their origin the different arteries are so connected, directly or indirectly, that the blood approaching the brain by way of the vertebral and internal carotid arteries is practically a common supply for all the arteries of the encephalon, and a given part of it may possibly pass into any one of them. (2) In the pia mater of each division of the encephalon the different arteries again become connected with each other in a superficial, freely anastomosing plexus, continuous throughout. (3) From this plexus of the surface, naturally composed in part of the trunks of the different arteries themselves, arise branches which enter directly into the nervous substance and which break up into twigs that are *terminal;* i.e., twigs that do not anastomose with each other. (4) The arterial capillary system arising from the terminal twigs passes over into venous capillaries which converge to form corresponding venous twigs which in their turn pass to the surface and join in forming a peripheral, anastomosing venous plexus superimposed upon the similar arterial

Fig. 653.—Diagram Showing the Manner of Distribution of the Cortical and Central Branches of the Cerebral Arteries.



plexus. (5) From this venous plexus arise the different veins of the encephalon which may or may not accompany the arteries for a short distance, and which finally empty into the sinuses in the cranial dura mater. These, likewise confluent, empty into the internal jugular veins. The chorioid plexuses of the ventricles of the brain are modifications of the general anastomosing peripheral plexuses. The chorioid plexuses of the lateral and third ventricles are derived largely from branches of the *arteria chorioidea,* which arises separately from the internal carotid artery.

The **blood supply of the cerebrum** may best be taken as an illustration of the general plan of the blood-vascular system of the encephalon. The terminal or internal branches of the surface plexus, derived from the posterior, middle, and anterior cerebral arteries, are arranged into two groups, a **central** or **ganglionic** and a **cortical group.** The central or ganglionic branches themselves form four groups in each hemisphere:—

(1) The *antero-mesial group* consists of terminal branches from the plexus of the domain of the anterior cerebral artery, which pass through the medial part of the anterior perforated substance and supply the head of the caudate nucleus, the septum pellucidum, the columns of the fornix, and the lamina terminalis.

(2) The *antero-lateral group* consists of terminal branches from the domain of the middle cerebral artery. These pierce the anterior perforated substance in two sub-groups—(*a*) the internal and (*b*) the external striate arteries (fig. 653). The **internal striate arteries** pass through the segments of the globus pallidus of the lenticular nucleus and through the internal capsule, to both of which they give branches, and they terminate in the caudate nucleus and thalamus. The **external striate arteries** are larger and more numerous. They pass upwards

between the external capsule and the putamen, and then through or around the upper part of the putamen into the internal capsule, where they form two groups, the *lenticulo-thalamic* and the *lenticulo-caudate groups.* The former terminate in the thalamus and the latter in the caudate nucleus. On account of its larger size at its origin and its direct linear continuation with the internal carotid, emboli pass more frequently into the middle cerebral artery than into the anterior cerebral artery. One of the lenticulo-caudate arteries which is larger and longer than the others and which is a direct branch from the middle cerebral artery has been called the **'artery of cerebral hemorrhage'** (Charcot), on account of the greater frequency with which it is ruptured.

(3) The *postero-medial central* or ganglionic arteries are terminal branches of the posterior cerebral artery. They also enter the anterior perforated substance, but supply the floor of the third ventricle, the posterior part of the thalamus, and the hypothalamic region.

(4) The *postero-lateral group* are also terminal branches of the posterior cerebral artery. They supply the posterior part of the internal capsule, the pulvinar of the thalamus, the geniculate bodies, the corpora quadrigemina and their brachia, the epiphysis, and the cerebral peduncles.

The *cortical group* of the cerebral arteries arise from the anastomosing plexus in the pia mater of the cortical surfaces of the hemisphere. They pass into the cortical substance both from the summits of the gyri and from the walls of the sulci. They consist of short, medium, and long branches, and pass at right angles into the gyri. The short branches terminate in the cortical substance; the medium branches supply the more adjacent white substance, and the longer branches pass more deeply into the general medullary centre of the hemisphere.

All of both the central or ganglionic and the cortical arteries are terminal in the sense that they do not anastomose in the substance of the cerebrum.

The blood-vascular system of the other divisions of the encephalon is in accordance with the same general plan of that of the cerebrum. Slight individual modifications of the general plan are to be expected.

The **blood-vessels of the mesencephalon,** in addition to the supply derived from the postero-lateral group of central arteries, include the vessels of the quadrigeminate bodies and those of the cerebral peduncles. The **arteries** of the quadrigeminate bodies are usually six in number, three for each side—the **superior, middle,** and **inferior quadrigeminate arteries.** The superior and middle are branches of the posterior cerebral arteries, and the inferior are branches of the superior cerebellar arteries. The superior supply the superior quadrigeminate bodies and the epiphysis; the middle supply both the superior and inferior quadrigeminate bodies, and the inferior the inferior quadrigeminate bodies. They all anastomose on the surface of the stratum zonale, forming a fine-meshed plexus, and from this plexus the terminal branches pass into the substance of the bodies. The **veins** terminate in the vein of Galen (v. cerebri magna).

The **arteries of the cerebral peduncles** form two groups, mesial and lateral. The **mesial peduncular arteries** are branches of the basilar and the posterior cerebral arteries. They pass to the inner sides of the peduncles and supply the upper and inner part of the tegmentum. The vessels of this group which accompany the fibres of the third nerves are known as the radicular arteries; they supply the root-fibres and the nuclei, which receive no other branches. The **lateral peduncular arteries** are branches of the posterior cerebral and superior cerebellar arteries. They supply the lateral portions of the peduncles and the outer part of the tegmentum. The **veins** of the mid-brain terminate in the basilar veins and the vein of Galen.

The Blood-vessels of the Cerebellum.—**Six arteries** supply the cerebellum; two, the **posterior inferior cerebellar,** are derived from the vertebral arteries, and the remaining four, two **anterior inferior** and two **superior cerebellar,** from the basilar artery. The course and general distribution of the arteries are described in Section V, but here it must be noted that the branches of these six vessels form a rich network in the pia mater on the surfaces of the cerebellar lobes, and that extensions of the plexus pass with the folds of the pia mater into the sulci and fissures. From the superficial plexus terminal branches pass into the interior of the cerebellum and their collaterals form capillary plexuses in the white and grey substance. The extensions of the surface plexus are of three lengths:—(1) a longer set, which pass through the cortex of the cerebellum and supply the white substance of the corpus medullare; (2) a set of shorter arterioles which pass through the molecular layer of the cortex and break up in the granular layer; (3) the shortest set pass into the cortex and immediately break up in the molecular layer. The meshes of the capillary plexuses in the grey substance are ovoidal and their axes run radially. The meshes of the plexuses in the white substance are parallel with the nerve-fibres. In addition to the vessels mentioned, a distinct branch is distributed to each dentate nucleus. This springs either from the superior cerebellar or from the anterior inferior cerebellar artery of the corresponding side.

The **efferent veins** of the cerebellum do not accompany the arteries; they spring from a plexus in the pia mater which receives tributaries from the interior, and they form three groups on each surface, the vermian veins and the lateral veins. The **superior vermian vein** runs forwards on the upper surface of the vermis and terminates in the vein of Galen. The **inferior vermian vein** runs backwards and ends in one of the transverse sinuses. The **upper lateral veins** open into the superior petrosal or transverse sinuses, and the **lower lateral veins** into the inferior petrosal and transverse sinuses. The vein from the dentate nucleus usually joins the lower lateral veins.

The Blood-vessels of the Pons.—The arteries to the pons are branches of the basilar artery, and of its anterior inferior and superior cerebellar branches. The reticulum in the pia mater is comparatively unimportant, and the branches which enter the substance of the pons form two main groups, the central and the peripheral. The **central arteries** spring directly from the basilar. They pass backwards along the raphe, giving branches to the adjacent parts, and they terminate in the nuclei in the floor of the fourth ventricle. The **peripheral arteries** are radicular and intermediate. The *radicular branches* spring from the peripheral plexus and from the anterior inferior cerebellar arteries; they accompany the roots of the fifth, **sixth, seventh, and**

eighth nerves, supply their fibres and the adjacent parts, and they end in the grey nuclei with which the nerve-fibres are connected. The *intermediate arteries* enter the surfaces of the pons irregularly and break up into capillaries in its substance. **The veins** form a plexus on the surface. The upper and lateral part of this plexus is drained into the basilar vein on each side, and the lower part is connected by efferent channels with the inferior petrosal sinus and the cerebellar veins.

The Blood-vessels of the Medulla Oblongata.—The **arteries of the medulla** are derived directly from the vertebral arteries, from their anterior and posterior spinal and posterior inferior cerebellar branches, and from the basilar artery. The branches of these vessels form a plexus in the pia mater from which, and from the arteries themselves, three main groups of vessels pass into the medulla—the chorioidal, the central, and the peripheral. The **chorioidal arteries** are derived chiefly from the posterior inferior cerebellar arteries. Their relation to the medulla is described on p. 546. The **anterior central arteries** rise from the anterior spinal arteries, from the basilar artery, and from the peripheral plexus; they pass backwards along the raphe, supplying the adjacent parts of the ventral funiculi and the olivary bodies, and they break up into fine terminals in the grey substance of the floor of the fourth ventricle around the nuclei of the cranial nerves. The **posterior central arteries** spring from the posterior spinal arteries; they pass down the median septum of the lower part of the medulla and supply the adjacent

FIG. 654.—SHOWING THE CAPILLARY SUPPLY OF THE CEREBELLAR CORTEX. (After Aby, "Journal of Comparative Neurology," Vol. IX.)

nervous substance. The **peripheral arteries,** like those of the spinal cord, are separable into radicular and intermediate groups. The *radicular arteries* pass from the anterior and posterior spinal branches and from the trunks of the vertebral arteries and accompany the fibres of the last four cranial nerves into the substance of the medulla. They supply the nerve-roots and adjacent white substance and they terminate in capillaries in the grey substance of the lateral part of the floor of the ventricle. The *intermediate peripheral arteries* spring from the arteries previously named and from the peripheral plexus, and they pass directly into the columns of the medulla, where they terminate in a capillary plexus which supplies the white substance and the grey nuclei; some of these arteries, more especially those derived from the posterior inferior cerebellar and the posterior spinal arteries, extend inwards to the lateral part of the floor of the fourth ventricle.

The veins which issue from the medulla form a peripheral plexus in the pia mater in which there are two main longitudinal channels, an **anterior median** and a **posterior median vein.** The former communicates below with the anterior median vein of the cord, and above with the veins of the pons and with the veins which accompany the hypoglossal nerves. The latter veins empty into the internal jugular veins. The posterior median vein is continuous below with the corresponding vein of the cord, and above, in the region of the calamus scriptorius, it divides into branches which join the radicular veins. The blood is carried away from the peripheral

plexus mainly by the **radicular veins,** which pass along the roots of the last four cranial nerves. Those which accompany the hypoglossal nerves have already been referred to. The others end in the terminal parts of the transverse sinuses, the inferior petrosal sinuses, or the lower part of the occipital sinuses.

The **nerve supply of the blood-vessels** of the brain consists of a perivascular plexus of sympathetic nerve-fibres upon the walls of the vessels and medullated fibres which accompany the vessels and apparently terminate, for the most part, in the connective tissue about them. The former are thought to be vaso-motor in function; the latter probably sensory fibres of the cerebro-spinal type. Nerves have been described only for the larger vessels.

THE MENINGES

Three membranes, collectively called the **meninges,** envelope the entire central nervous system, separate it from the walls of the bony cavities in which it lies, and aid in its protection and support. They consist of feltworks in which white fibrous connective tissue predominates, and through them pass the blood-vessels which supply the central nerve-axis and the nerves by which the axis is connected with the periphery. Though there are definite spaces or cavities between them, the membranes are not wholly separated from each other, and they are both continuous with and contribute to the walls of the blood-vessels and the sheaths (epineurium) of the nerves passing through them. Beginning with the outermost, they are—(1) the dura mater, the thickest, most dense, and resistant of the membranes; (2) the arachnoid, the much less dense and more serous middle membrane; and (3) the pia mater, a thin, compact membrane, closely adapted to the surface of the central system, into which it sends numerous connective-tissue processes. It is highly vascular in that it contains the rich superficial plexuses of blood-vessels from which the intrinsic blood supply of the central system is derived. The space between the dura mater and the arachnoid is known as the **sub-dural cavity,** and that between the arachnoid and the pia mater is the **sub-arachnoid cavity.**

The Dura Mater

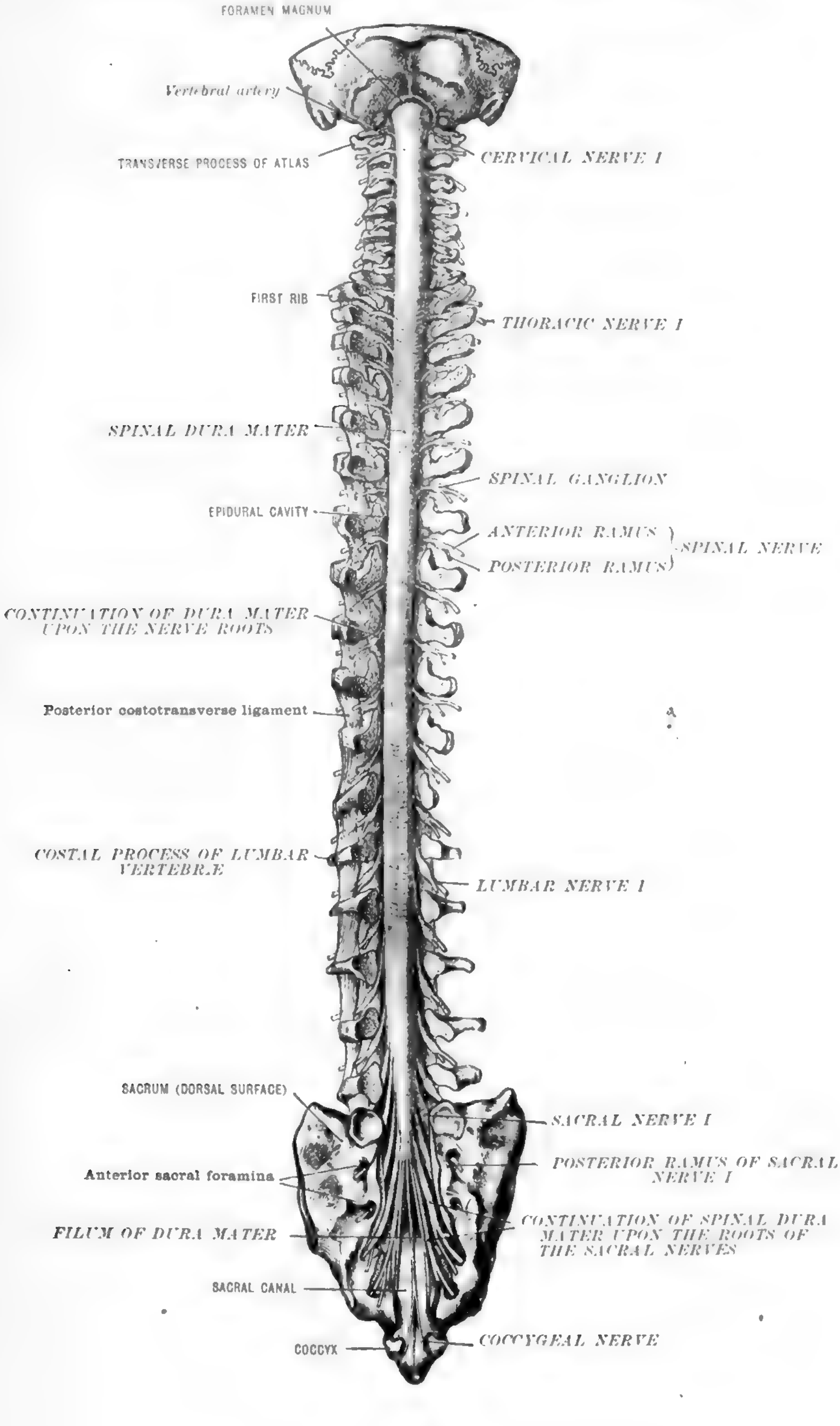
In the fresh condition the dura mater appears as a bluish-white, exceedingly resistant membrane, forming the outermost envelope of the entire central nervous system. Its external surface or that next to the bony wall is rough, while its internal surface appears smooth, due to the fact that the subdural cavity partakes of the nature and has the lining of a lymph-space. The cranial dura mater consists of two distinct, closely associated layers, the outermost of which serves as the internal periosteum of the cranial bones. The spinal dura mater is described as consisting of but one layer. The internal periosteum of the spinal canal, though continuous at the foramen magnum with the outer layer of the cranial dura mater, is not considered a part of the spinal dura mater, from the fact that it is so widely separated from the layer actually investing the spinal cord. Thus, since the cranial and spinal portions of the dura mater differ, they are described separately.

The spinal dura mater is a fibrous tube with funnel-shaped termination which encloses and forms the outermost support of the spinal cord. It consists of but one layer, and this corresponds to the inner layer of the cranial dura mater. It begins at the foramen magnum and terminates in the spinal canal at about the level of the third piece of the os sacrum. It is firmly attached to the periosteum of the surrounding bones only in certain localities:—

(1) The upper end of the tube blends intimately with the periosteum of the margin of the foramen magnum, and thus in this locality it becomes continuous with the outer layer of the cranial dura mater. Also in this locality it is attached firmly, though less intimately, to the periosteum of the posterior surfaces of the second and third cervical vertebræ. This locality may be considered the upper fixation-point of the spinal dura mater. (2) It extends laterally and contributes to the connective tissue investments of each pair of spinal nerves, and as such it passes into the intervertebral foramina and becomes loosely connected with the periosteum lining each. (3) Along its ventral aspect the spinal dura mater is attached by numerous processes to the posterior longitudinal ligament of the vertebral canal. These attachments are more or less delicate, loose, and irregular, and are easily torn or cut in removing the specimen. They are stronger and more numerous in the cervical and lumbar regions than

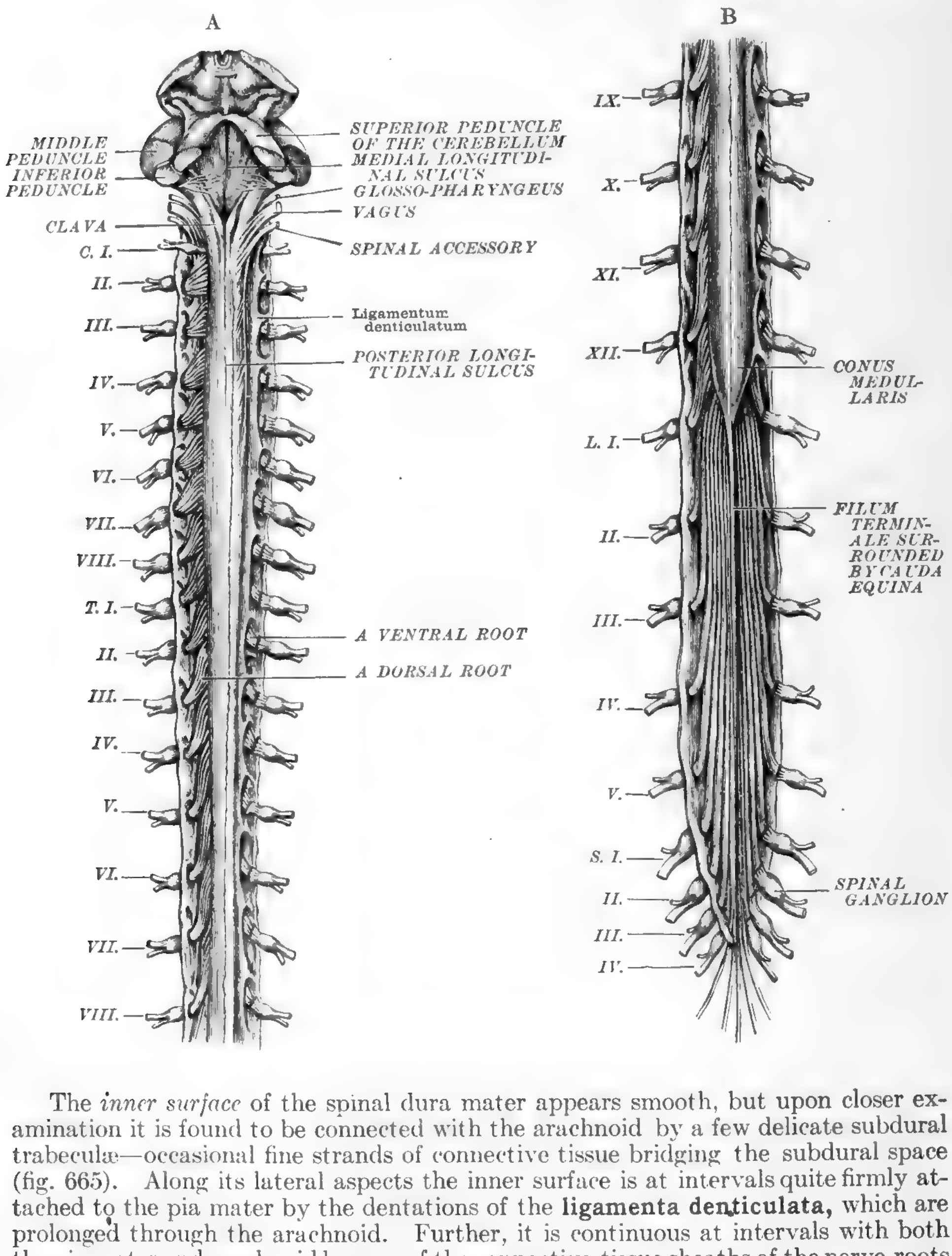
in the thoracic. (4) In the space between the dura and the walls of the vertebral canal (*epidural cavity*) lies the rich internal vertebral venous plexus, and along the lateral aspect the dura is occasionally connected with the periosteum through the tissue of the walls of the vessels of this plexus, especially in case of the vessels which

FIG. 655.—SHOWING THE SPINAL DURA MATER EXPOSED *in situ*. (Dorsal aspect.) (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



penetrate the dura. Along its dorsal aspect the spinal dura mater is practically free from the wall of the vertebral canal. (5) At its lower and funnel-shaped extremity, opposite the second sacral vertebra, the tube suddenly contracts into a filament extending into the coccyx and breaking up into a number of processes which become continuous with the periosteum of the dorsal surface of the coccyx. This filament is the **coccygeal ligament** or *filum* of the dura mater, and its attachment may be considered the lower fixation-point of the spinal dura mater. The extent of the tube is maintained chiefly by means of the two fixation-points, for all the other attachments are sufficiently loose to permit of the movements of the vertebral column.

FIG. 656.—DORSAL ASPECT OF THE MEDULLA OBLONGATA AND SPINAL CORD WITH THE DURA MATER PARTIALLY REMOVED. (Hirschfeld and Leveillé.)



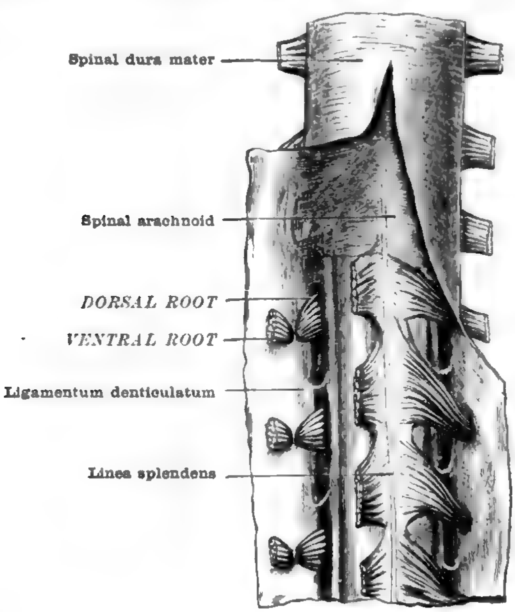
The *inner surface* of the spinal dura mater appears smooth, but upon closer examination it is found to be connected with the arachnoid by a few delicate subdural trabeculæ—occasional fine strands of connective tissue bridging the subdural space (fig. 665). Along its lateral aspects the inner surface is at intervals quite firmly attached to the pia mater by the dentations of the **ligamenta denticulata,** which are prolonged through the arachnoid. Further, it is continuous at intervals with both the pia mater and arachnoid by way of the connective-tissue sheaths of the nerve-roots which are prolonged from the pia and blend with the dura mater in the passage of the

nerve-roots through it. The dura is also pierced by the spinal rami of the vertebral arteries, and the connective tissue of the outer walls of these vessels blends with all three of the meninges. The filum terminale of the pia mater extends below the termination of the spinal cord into the point of the funnel-shaped end of the dura mater, and there blends with it in line with the coccygeal ligament of the outer surface.

The tube of the spinal dura mater varies in calibre with the variations in the diameter of the spinal cord. However, the termination of its cavity occurs about seven segments below the termination of the spinal cord. This extension contains the long intra-dural nerve-roots forming the cauda equina, and the calibre of this part, before its sudden contraction, is about as great as that found in any other region. As each pair of nerve-roots of the cauda equina passes outwards, they lie free for a variable distance in a tubular extension of the dura before the latter blends with and contributes to the thickness of their sheath.

The **subdural cavity,** the space between the dura mater and the arachnoid, is the thinnest of the meningeal spaces. Along the ventral aspect especially, the spinal arachnoid is quite closely applied to the inner surface of the dura mater. It contains a small amount of cerebro-spinal fluid (lymph) which prevents friction between

FIG. 657.—VIEW OF MEMBRANES OF SPINAL CORD FROM VENTRAL ASPECT. (Ellis.)



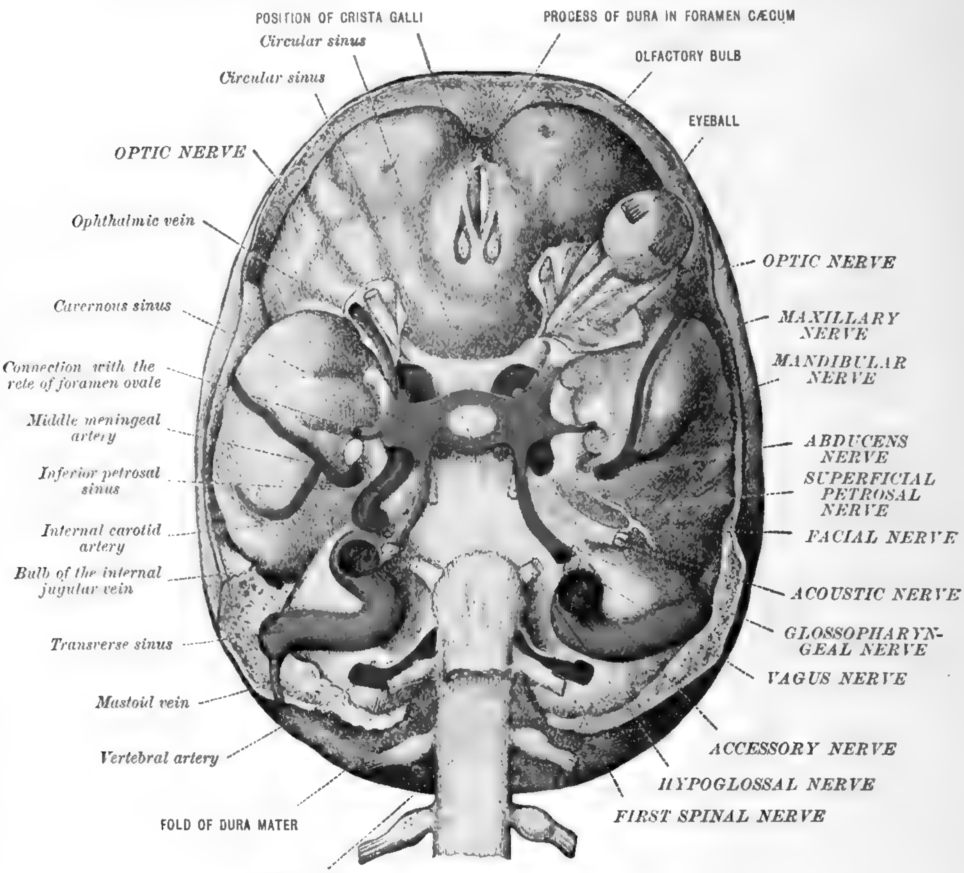
the opposing surfaces, and is continuous with the fluid in the like space of the cranial meninges. The space communicates with the venous sinuses of the cranium in the region of the Pacchionian bodies, and its fluid is likewise in contact with the blood-vessels passing through it. It is probably continuous with the lymph-spaces of the nerve-roots passing through it, for colored fluids injected into it pass into the nerve-roots. The arachnoid is so thin and gauze-like that a ready interchange of fluids between this space and the subarachnoid space is possible by simple filtration.

The cranial dura mater.—The dura mater investing the brain performs a double function—it serves as an internal periosteum for the cranial bones and gives support and protection to the brain. In conformity with its double function it consists of two layers, easily separable in the child, but closely adhering to each other in the adult, except in occasional localities, where there exist small clefts lined with epithelium. The large blood sinuses and venous lacunæ are placed between the two layers and the semilunar ganglia of the trigemini also lie between them. The cranial dura begins with the adhesion of the spinal dura mater to the periosteum of the foramen magnum, and it forms a sac-like envelope about the entire encephalon. Consisting of two layers, it is a much thicker membrane than that of the spinal cord.

The *outer surface* of the cranial dura mater when torn away from the cranial

bones appears very uneven, and when placed in water presents a flocculent appearance. This is due to the many fine bundles of connective tissue and the blood-vessels which pass between the dura and the cranial bones and which are partially pulled out of their openings in the latter in the process of separation. The abundance of these connections, and, therefore, the degree of adhesion to the bones, varies in different localities. The separation is much less difficult from the inner table of the bones of the vault of the cranium than from the bones of the base of the cavity. The adhesions to the vault of the cranium are most firm along the lines of the sutures. This is due to the fact that during the period before the sutures are closed the outer layer of the dura mater is directly continuous with the external periosteum, and, in consequence of this condition during development, the connective-tissue connection is more

Fig. 658.—The Dura Mater Encephali of the Base of the Cranium. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



abundant along these lines and some is even caught in the closure of the sutures. Along the vault there are occasionally noticed small lymph-spaces between the bone and the dura mater. The stronger adherence to the base of the cranial cavity is due to the numerous foramina in the floor, through which all the larger cranial blood-vessels and the cranial nerves pass, and the dura mater is continuous with the connective-tissue investments of these as well as with the periosteum lining the foramina. Also the floor of the cavity is more uneven than the vault, and the projections of the bones here tend to increase the firmness of attachment. The weight of the brain upon the floor probably contributes to the result.

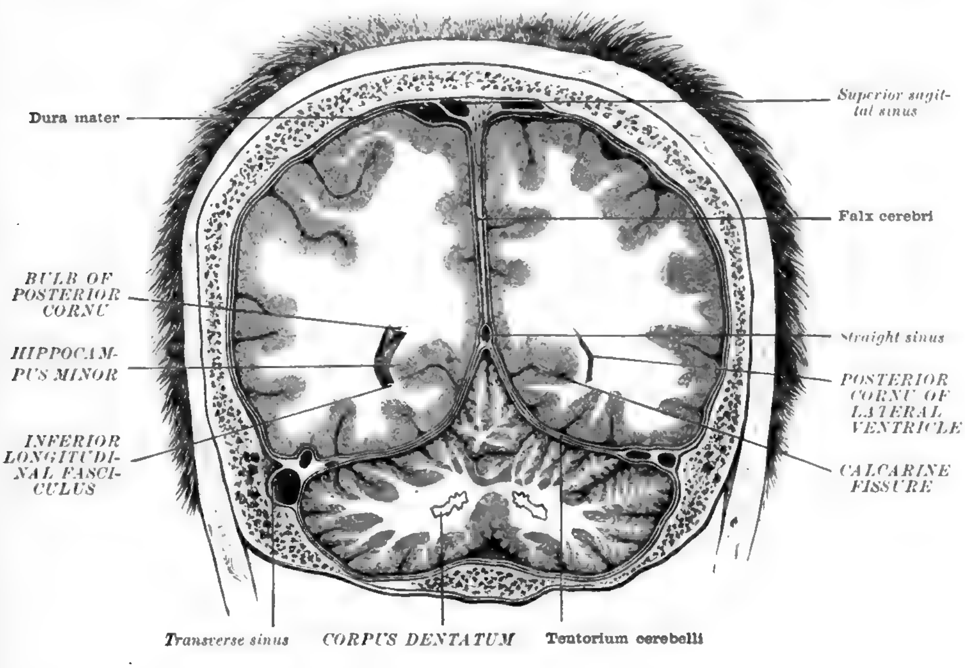
The *inner surface* of the inner layer of the cranial dura mater forms the outer boundary of the subdural cavity. Except for the occasional delicate subdural trabeculæ and the passage of blood-vessels and nerve-roots, this surface appears smooth and

glistening, being lined by a layer of endothelium and containing a small amount of the cerebro-spinal lymph.

The subdural cavity of the base of the brain is prolonged a short distance outwards along the roots of the various cranial nerves before it is obliterated by the blending of the dura mater with the sheaths of the nerves. This outward extension of the space is most marked about the optic and auditory nerves. In the optic especially, the dura mater remains separate from the nerve throughout its length, only fusing with its sheath upon the posterior surface of the bulbus oculi (fig. 658).

One of the most striking differences between the cranial dura mater and that of the spinal cord is that the inner layer of the former undergoes striking septa-like duplications or folds, forming exceedingly strong partitions which project between the larger subdivisions of the encephalon. These are four in number, two large and two small—the falx cerebri and the tentorium cerebelli; the falx cerebelli and the diaphragma sellæ. The larger enclose within their folds the great venous sinuses, into which most of the spent blood of the encephalon collects to pass outwards by way of the internal jugular veins.

Fig. 659.—Coronal Section of the Head, Passing through the Posterior Horns of the Lateral Ventricles.
(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)



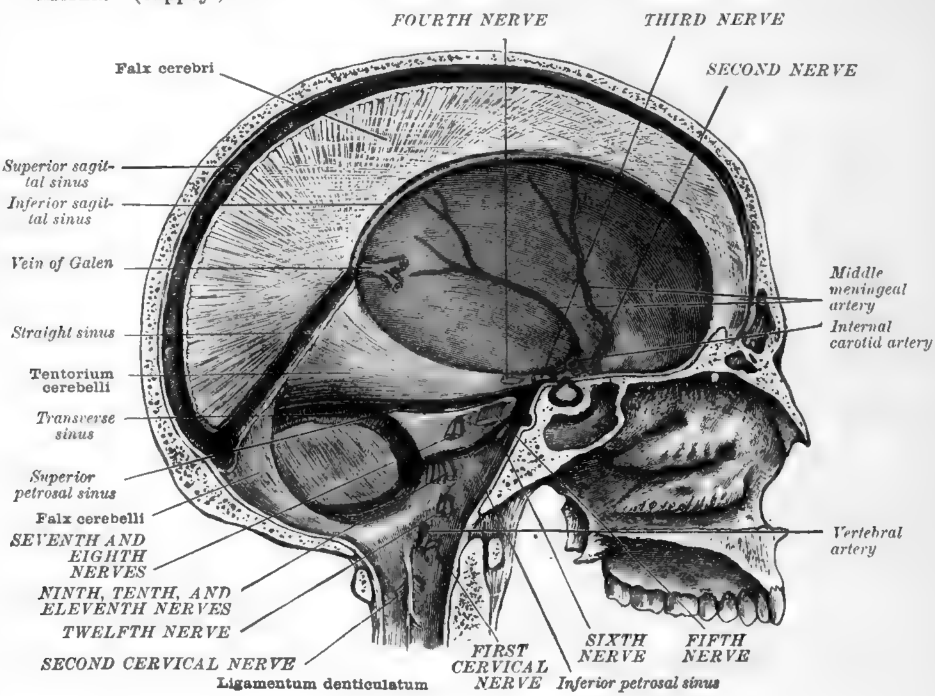
The **falx cerebri** is the most striking of these partitions. It is a sickle-shaped fold which projects vertically from the vault into the longitudinal fissure between the cerebral hemispheres. It begins attached to the crista galli in front, and arches backwards to terminate by blending with the superior surface of the horizontally placed tentorium cerebelli. Its convex, upper border joins the outer layer of the dura along the medial plane of the vault, and encloses the superior sagittal sinus. Its concave border is free and contains in its posterior two-thirds the smaller inferior sagittal sinus. The anterior and narrower end is often perforated and occasionally so much so as to appear as a coarse, fibrous reticulum. The posterior part of the concave border touches the upper surface of the corpus callosum, but the anterior part, which does not descend so low, is separated from the corpus callosum by a part of the subarachnoid space. The base of the fold which slopes downwards and backwards and blends with the upper surface of the tentorium cerebelli, contains the straight sinus running along the line of junction.

The **tentorium cerebelli** is a large semilunar fold, concave forwards. It de-

scends from its central part which is elevated, and consequently it forms a tent-shaped covering. Its upper surface is in relation with the tentorial surfaces of the hemispheres, and its lower surface conforms accurately to the upper surface of the cerebellum. The outer or convex border of the fold is attached on each side to the posterior clinoid process, the superior border of the petrous portion of the temporal bone, the mastoid portion of the temporal bone, the posterior inferior angle of the parietal bone, and the horizontal ridge of the occipital bone. The transverse sinus lies in this border. From the internal occipital protuberance to the mastoid portion of the temporal bone and along the petrous part of the temporal bone it encloses the superior petrosal sinus.

The greater part of the inner or anterior border of the tentorium is free, and it forms the superior and lateral boundaries of an arched cavity, the **tentorial notch** or foramen ovale of Pacchioni, which encloses the mesencephalon, and through which ascend the cerebral peduncles and the posterior cerebral arteries. The anterior extremities of the inner border cross the outer border, and they are attached to

Fig. 660.—The Cranium with Encephalon Removed to show the Falx Cerebri, the Tentorium Cerebelli, and the places where the Cranial Nerves pierce the Dura Mater. (Sappey.)



the anterior clinoid processes. A depressed angle is formed between the inner and outer borders of the tentorium in the middle fossa of the skull at the outer side of the posterior clinoid process, and in this angle the root of the third nerve pierces the inner layer of the dura mater.

The **falx cerebelli** is a small, sickle-shaped, triangular fold which projects downwards and forwards, into the small groove (*posterior cerebellar notch*), between the hemispheres of the cerebellum. Its base is attached to the tentorium; its superior border, along which runs the occipital sinus, is attached to the internal occipital crest. Its anterior border is free, and its apex, which lies immediately behind the foramen magnum, usually bifurcates as it disappears anteriorly, grasping the foramen magnum from behind. Bifurcation is always the case when the internal occipital crest splits below to enclose a vermiform fossa.

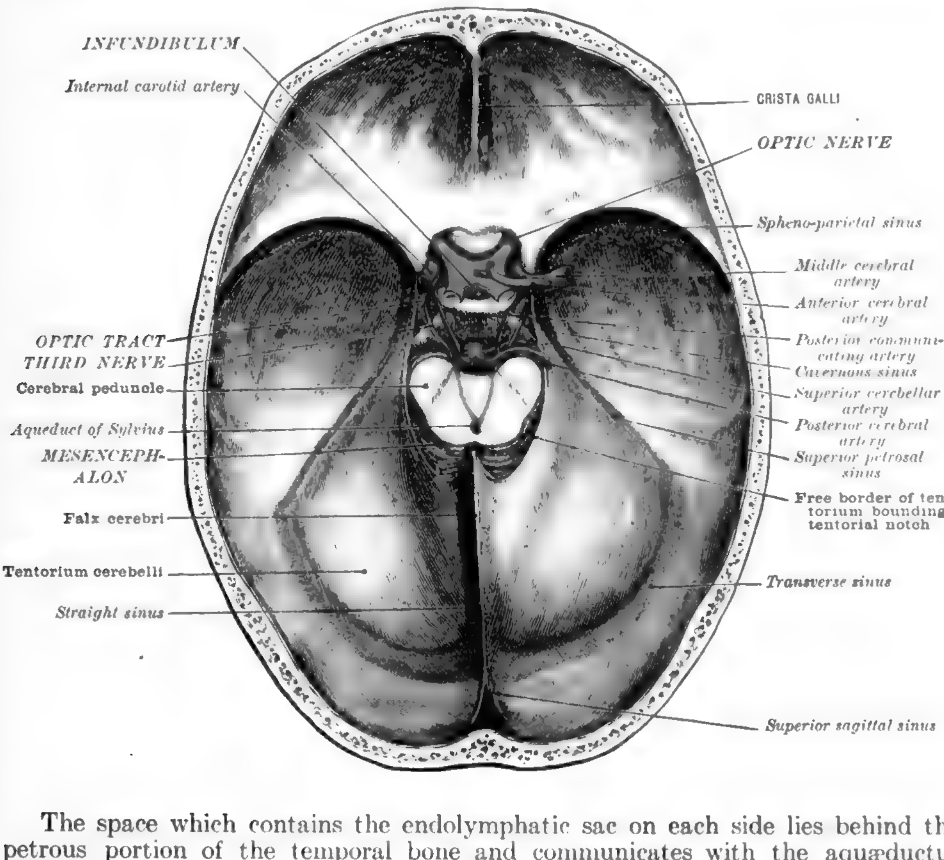
The **diaphragma sellæ** is a small circular fold, deficient in the centre, which projects horizontally from the margins of the hypophyseal fossa or sella turcica. Its outer border is attached to the clinoid processes and the limbus of the sphenoid,

and its inner border forms the boundary of the *foramen of the diaphragma sellæ* and surrounds the infundibulum. Its upper surface is in relation with the base of the brain, and its lower surface is in relation with the hypophysis, which it binds down in the hypophyseal fossa.

The spaces which lie between the layers of the cranial dura mater are Meckel's caves, the spaces which lodge the endolymphatic sacs, and the blood sinuses and lacunæ.

Meckel's caves are two cleft-like spaces or niches which lie, one on each side, in the trigeminal impression on the apex of the petrous portion of the temporal bone. Each space lodges the semilunar (Gasserian) ganglion and the motor and sensory roots of the trigeminus of the corresponding side, and it communicates with the subdural space in the posterior fossa of the cranium by an oval opening, which lies above the superior border of the petrous portion of the temporal bone and below the superior petrosal sinus.

FIG. 661.—SHOWING THE UPPER SURFACE OF THE TENTORIUM CEREBELLI AND THE TENTORIAL NOTCH THROUGH WHICH THE MID-BRAIN AND POSTERIOR CEREBRAL ARTERIES ENTER THE MIDDLE FOSSA OF THE CRANIUM.



The space which contains the endolymphatic sac on each side lies behind the petrous portion of the temporal bone and communicates with the aquæductus vestibuli.

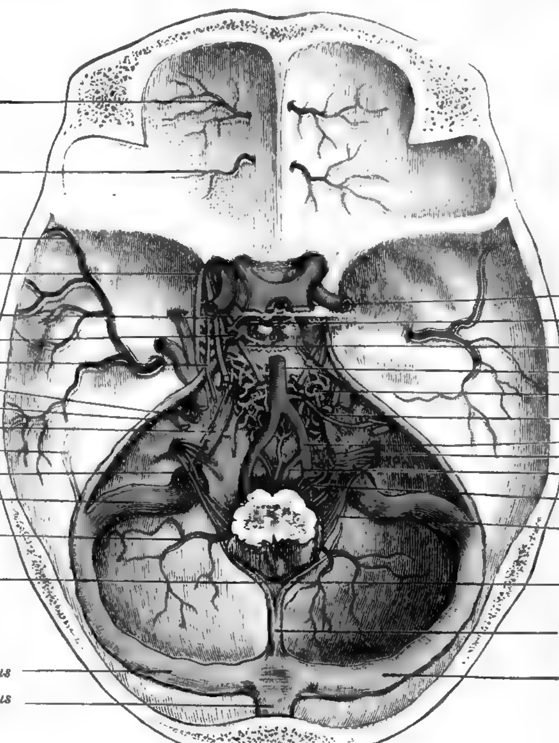
The venous sinuses and lacunæ.—The cranial blood sinuses have already been fully described in the account of the vascular system, and it is sufficient to note here that they are continuous, on the one hand, with the meningeal veins, and, on the other, with the veins outside the cranial walls. The vessels which establish communication between the blood sinuses and the extracranial veins are referred to collectively as **emissary veins.** They possibly help to maintain the regularity of the cranial circulation, and they have therefore a certain amount of practical importance.

The sinuses which are connected with the extracranial veins by emissary veins are the superior sagittal, the transverse (lateral), and the cavernous. Three or four emissary veins pass from the superior sagittal sinus:—one passes through the foramen cæcum and communicates with the veins of the roof of the nose, or, through the nasal

bones, with the angular veins. Two pass through the parietal foramina and establish communications with the occipital veins, and a fourth, which is very inconstant, pierces the occipital protuberance and joins the tributaries of the occipital veins. Connecting each lateral sinus with the extracranial veins there are, as a rule, two emissary veins:—one, the mastoid emissary vein, which passes through the mastoid foramen to the occipital or posterior auricular vein; and the other, the post-condyloid vein, which traverses the condyloid (posterior condyloid) foramen and joins the suboccipital plexus. The cavernous sinus is in communication anteriorly with the superior ophthalmic vein, and through the latter with the angular vein; it is connected with the pterygoid plexus by emissary veins which pass either through the foramen ovale or the foramen Vesalii, and with the pharyngeal plexus by small venous channels which accompany the internal carotid artery through the carotid canal.

Fig 662.—Showing Blood-vessels of Cranial Dura Mater and Cranial Nerves in the Base of the Skull.

(On the left side the dura mater has been removed in the middle fossa.)



The **Venous Lacunæ** or spaces are small clefts lined by endothelium which communicate with the meningeal veins and with blood sinuses. They also have communications with the emissary veins and the diploic veins. They lie between the outer and inner layers of the dura mater, the majority of them at the sides of the superior sagittal sinus, but others are found in the tentorium associated with the transverse sinuses and the straight sinus.

Vessels.—The blood supply of the cranial dura mater is derived from the **meningeal arteries**, which ramify in its outer layer. The more important of these arteries have already been described in the account of the vascular system, and it is only necessary here to recall the fact that the greater part of the dura mater above the tentorium cerebelli is supplied by branches of the middle meningeal arteries. These are reinforced —(1) at the vertex by branches of the occipital arteries which enter through the parietal foramina; (2) in the middle fossa by the small meningeal arteries and by meningeal branches of the internal carotid, lachrymal, and ascending pharyngeal arteries; and (3) in the anterior fossa by meningeal branches of the anterior and posterior ethmoidal arteries.

The dura mater in the posterior fossa of the skull, below the tentorium cerebelli, also receives branches from the middle meningeal arteries, but its blood supply is derived mainly—(1) from the meningeal branches of the vertebral arteries which enter the fossa through the foramen magnum, (2) from meningeal branches of the occipital arteries which enter through the mastoid and condyloid foramina, and (3) from meningeal branches of the posterior auricular and ascending pharyngeal arteries which enter through the jugular and hypoglossal (anterior condyloid) foramina.

The **meningeal veins** accompany the arteries as *venæ comites*, usually one vein with each artery. The middle meningeal artery usually has two venæ comites. The meningeal veins communicate with the venous sinuses and with the diploic veins, and, unlike ordinary veins, they do not increase much in calibre as they approach their terminations.

The **nerves** of the dura mater are partly derived from the sympathetic filaments which accompany the arteries and partly from the cranial nerves. The nerves, other than sympathetic filaments, which supply the cranial dura mater are derived from the fifth and tenth cranial nerves, and possibly from the first cervical nerve. The branches from the trigeminus are derived from the first, second and third divisions of that nerve on each side, and it has been stated that branches are given from the nasal branch of the first division to the dura mater in the anterior fossa.

The meningeal branch of the first division of the trigeminus supplies the tentorium; that from the second division accompanies the branches of the middle meningeal artery. The meningeal branch of the third division (nervus spinosus) passes into the skull through the foramen spinosum and is distributed to the dura mater over the great wing of the sphenoid and to the mastoid cells. The recurrent branch of the hypoglossal nerve passes to the dura mater of the posterior fossa of the cranium. It is probable that this recurrent or meningeal branch of the twelfth nerve really consists of fibres derived either from the superior cervical ganglion of the sympathetic or from the first and second cervical nerves. The meningeal branch of the tenth nerve (vagus) springs from the ganglion of the root of that nerve, and is distributed in the posterior cranial fossa.

The cranial **subdural cavity** is not of uniform thickness throughout, being thinner along the basal aspect of the encephalon. The lymph contained in it is usually but little more than is sufficient to keep moist its bounding surfaces. It is continuous with the lymph capillaries of the nerves and those of all the tissues it bathes, and it is in communication with the similar cavity of the spinal canal. Its lymph is in free contact with the blood-vessels passing through it and with those in the tissues it bathes, and it is replenished by filtration through their walls. Though extensive, the subdural space is thin at best, for the dura mater is quite closely applied to the second of the three meninges.

The Arachnoid

The arachnoid or 'serous' membrane is the middle of the three meninges of the central nervous system. As in the case of the other two, an attempt is made to give this membrane a name descriptive of its texture. It is a gauzy reticulum of almost web-like delicacy, which in reality pervades the space it occupies. Its *outer surface*, or that closely related to the dura mater and bounding the subdural cavity, alone shows a sufficiently organized structure to merit the name of membrane. This surface is covered by a layer of endothelium which is identical with that lining the inner surface of the dura mater and is continuous with it by way of the endothelial cells covering the blood-vessels, the nerve-roots, the ligamenta denticulata of the spinal cord, and the occasional delicate trabeculæ passing between the dura mater and the arachnoid. Immediately under the endothelium, the connective-tissue fibres of the arachnoid are woven into a very thin, more or less compact feltwork. This, however, quickly grades into a loose, spongy reticulum which pervades the thick subarachnoid cavity throughout, and the strands of which are directly continuous into the more compact tissue of the pia mater. Thus an *inner surface* can hardly be claimed. This loose, sponge-like arachnoid tissue holds the cerebro-spinal fluid of the subarachnoid cavity, the meshes of the sponge constituting a reticular web of intercommunicating spaces lined by endothelioidal cells covering the strands of the web. The cranial subarachnoid cavity is larger, and the strands of the web are relatively more abundant than in that of the spinal canal. In addition, the cavity is traversed by the spinal and cranial nerves, by the blood-vessels passing to and from the pia, and, in the spinal canal distinctively, it is traversed by the ligamenta denticulata and the filum terminale. Through these the arachnoid is further continuous with the pia mater.

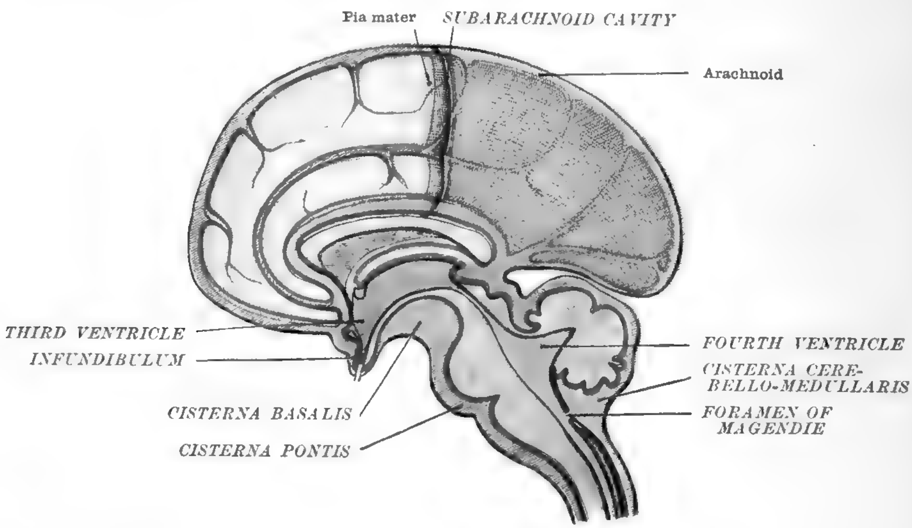
The cranial arachnoid is directly continuous into that of the spinal cord, and in the two localities does not differ as much as does the dura mater. Within the cranium, the arachnoid does not closely follow the surface of the encephalon. It is folded in between the cerebellum and cerebral hemispheres, following the contour of the tentorium cerebelli, but it does not dip into the fissures and sulci except the ante-

rior part of the longitudinal fissure and slightly into the lateral (Sylvian) fissure. Otherwise it fills in the inequalities of surface of the encephalon, its outer surface forming a sheet enveloping the whole and bridging over the sulci and the deeper grooves between the gross divisions. Upon the summits of the gyri it is more closely applied to the pia mater, and there its reticulum becomes so dense that the two membranes almost appear as one. The sulci, occupied by the looser reticulum, form a continuous system of channels filled more abundantly by the cerebro-spinal fluid.

The arachnoid does not fold in between the cerebellum and medulla oblongata, and at the base of the brain it ensheathes the olfactory bulbs and tracts, and its outer surface forms a continuous sheet stretching from one temporal lobe to the other and bridging over the interpeduncular fossa and the inequalities of surface in the region of the optic chiasma and the stems of the lateral fissures. Obviously, therefore, the subarachnoid cavity between its outer surface and the pia mater is of considerable depth in certain localities. These localities comprise the *subarachnoid cisternæ*. These make the cavity at the base of the brain especially large, and make possible a 'water-bed' which serves to protect the brain from injurious contact with the bones. The following cisternæ are distinguished:—

(1) **The cisterna basalis** lies at the base of the cerebrum and is divided by the

Fig. 663.—Diagram showing the Relations of the Pia Mater, the Arachnoid, and the Subarachnoid Cavity to the Brain.



optic chiasma into two parts—(*a*) the *cisterna chiasmatis* and (*b*) the *cisterna interpeduncularis*.

(2) **The cisterna pontis** is situated about the pons, especially in its basilar sulcus and the transverse fissures of either border, and is continuous in front with the cisterna basalis and behind with the subarachnoid cavity of the medulla.

(3) **The cisterna superior** lies in the angle between the splenium of the corpus callosum, the superior surface of the cerebellum, and the upper surface of the mesencephalon, and is connected ventrally, around the cerebral peduncles, with the cisterna basalis.

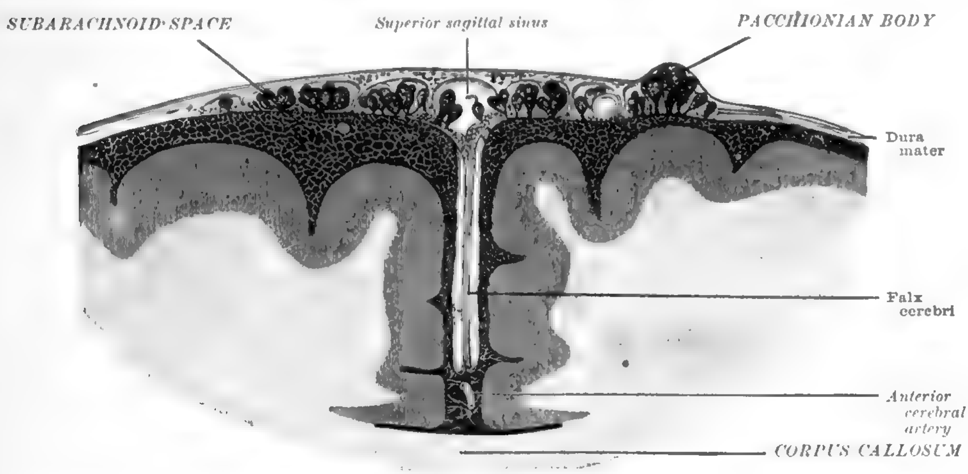
(4) **The cisterna cerebello-medullaris** (cisterna magna) is the cavity between the lower surface of the cerebellum and the upper surface of the medulla oblongata. It is continuous below with the spinal subarachnoid space. The fluid in this cavity is directly continuous with that in the fourth ventricle by way of the foramen of Magendie (median aperture of the fourth ventricle).

Pacchionian Bodies (*Arachnoid Granulations*).—In certain situations, more particularly on the vertex of the brain, along the margins of the longitudinal fissure, particularly in the frontal region, and to a much less extent upon the upper surface of the vermis of the cerebellum, the subarachnoid tissue proliferates and forms numerous small, ovoid or spherical nodules, the Pacchionian bodies. Each body or arach-

noid villus consists of a retiform network of subarachnoid substance and its meshes are filled with cerebro-spinal fluid. The Pacchionian bodies on the vertex of the brain project through the inner layer of the dura mater, either into the superior sagittal sinus or into the venous spaces or **parasinoidal sinuses** which lie at the sides of that sinus, and, as they become larger, they press against the outer layer of the dura mater and produce ovoid depressions on the inner surface of the cranium. They probably facilitate the passage of lymph from the subarachnoid cavity into the blood sinuses, and thus may aid in relieving pressure within. On the other hand, through them the cerebro-spinal fluid is replenished at need from the blood plasma. They are not present at birth, but they appear at the tenth year and increase in number and size with advancing age. They are less marked in the female than in the male.

The spinal arachnoid is in the form of a loose, reticular sac which is most capacious about the lumbar enlargement of the spinal cord and about the cauda equina. Like that of the encephalon, the portion next to the dura mater alone resembles a membrane, being a loosely organized feltwork, covered on the side of the subdural cavity by a layer of endothelium common to that cavity. Throughout its length the spinal subarachnoid cavity is relatively wide, and, as in the cranium, contains a fine, spongy, web-like reticulum, numerous threads of which are continuous with the pia mater. This spongy tissue is the inner modification of the arachnoid, and

FIG. 664.—CORONAL SECTION THROUGH THE GREAT LONGITUDINAL FISSURE, SHOWING THE MENINGES. (Key and Retzius.)

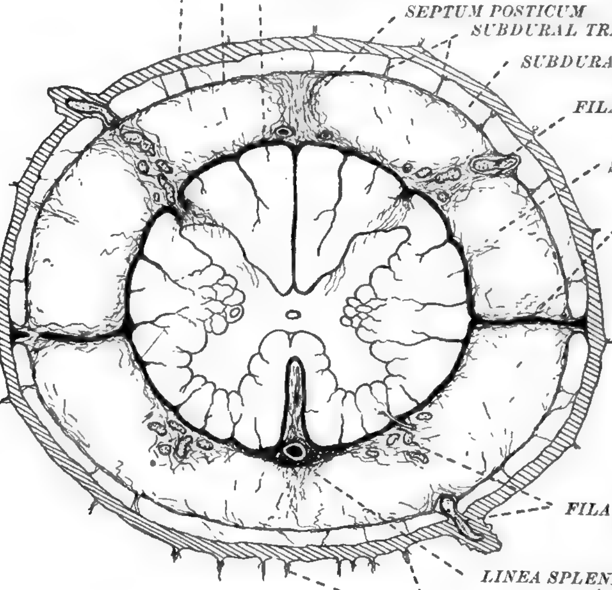


its meshes are occupied by the cerebro-spinal fluid. It is not so abundant as in the cranial subarachnoid cavity. In addition to the delicate threads of this tissue the arachnoid is more firmly attached to the pia mater by three incomplete partitions. The most continuous of these is arranged along the dorsal mid-line and is known as the **septum posticum** of Schwalbe (subarachnoid septum). This may be described as a linear accumulation of the spongy tissue which pervades the subarachnoid space. It is most incomplete in the upper cervical region, where it becomes merely a line of threads connecting with the pia. It is most complete as a septum in the lower cervical and in the thoracic region, but at best it maintains a spongy character. The other two partitions are formed by the **denticulate ligaments,** which extend laterally from either side of the spinal cord, connecting the pia and dura mater and involving the arachnoid in passing through it. Within the subarachnoid cavity these form more or less complete septa, though outside the arachnoid they are attached to the dura only at the intervals of their dentations. They belong to the pia mater and will be described with it. The arachnoid is further continuous with the pia by way of the connective-tissue sheaths of the roots of the spinal nerves and the blood-vessels passing through the subarachnoid cavity.

Vessels and Nerves.—The arachnoid has no special blood supply and probably no special nerves other than those supplying the walls of the blood-vessels passing through it.

The cerebro-spinal fluid.—The subarachnoid cavity is the great lymph-space of the central nervous system. That of the spinal region is directly continuous into that of the cranium, and the fluid contained communicates freely with that in the ventricles of the brain and the central canal of the medulla and spinal cord by way of the foramen of Magendie or aperture into the fourth ventricle. In addition, there is possible an interchange of fluid between the lateral ventricle and the subarachnoid cavity of the base of the brain by diffusion through the thin floor of the chorioid fissure. The arachnoid throughout is not a membrane sufficiently compact to seriously oppose diffusion between the fluid contained in its cavity and that contained in the subdural cavity, and the endothelium covering it probably even facilitates such activities. The cerebro-spinal fluid occupying the cavities is a transparent fluid of a slight yellow tinge, characteristic of the lymph in other lymph-spaces of the body. It is not very great in amount, probably never exceeding 200 c.c. in normal conditions. It is greatest in amount in old age, when the cavities are larger, due to atrophy and shrinkage of the nervous tissues. It collects from the lymph spaces in the meninges, and from exudation through the walls of the vascular plexuses and sinuses of the system it bathes. Its amount may be temporarily increased by a period of increased blood-pressure in the cranial vessels. Pressure due to its abundance may

Fig. 665.—Diagram of Transverse Section of Upper Thoracic Region showing the Relations of the Spinal Meninges and their Cavities.



be relieved by diffusion through the membranes containing it, and especially through the villi of the Pacchionian bodies into the venous sinuses and lacunæ and thence into the venous system through the internal jugular veins.

The Pia Mater

The **pia mater,** the third of the meninges, is a thin membrane which envelopes and closely adheres to the entire central nervous system and sends numerous processes into its substance. It likewise contributes the most proximal and compact portion of the sheaths worn by the nerve-roots in their passage through the meningeal spaces. It is very vascular in that the superficial plexuses of blood-vessels of both the brain and spinal cord ramify in it as they give off the central branches into the nervous substance. The structure and arrangement of the membrane vary somewhat in the cranial and spinal regions.

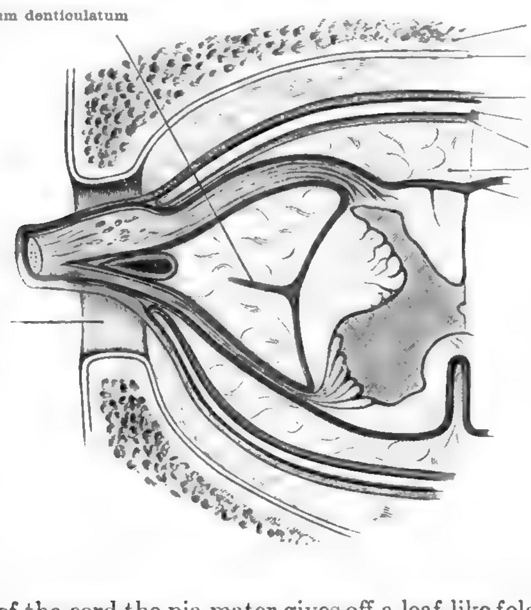
The spinal pia mater consists of two layers, an inner and an outer. It is thicker and more compact than that of the encephalon, due to the extra development of its outer layer, which is in the form of a strong, fibrous layer with the fibres arranged

for the most part longitudinally. The spinal pia mater also appears less vascular than the cranial from the fact that the blood-vessels composing the plexus lying in it are obviously much smaller than those of the encephalon. Its inner layer is a thin feltwork of fibres which is closely adherent to the surface of the spinal cord throughout, sending numerous connective-tissue processes into it which contribute to the support of the nervous tissues. The larger of these processes carry with them the numerous intrinsic blood-vessels from the superficial plexus. The two layers are closely connected with each other, and are distinguished by the difference in the arrangement of their fibres.

The membrane dips into the anterior median fissure and bridges it over by forming an extra thickening along it. This thickening appears as a band along the mid-line of the ventral surface of the cord, the **linea splendens** (fig. 657). It carries the anterior spinal artery, the largest of the arterial trunks of the superficial plexus (fig. 665).

The pia mater contributes the innermost and most compact portion of the epineurium of each of the nerve-roots, and thus, upon the roots, it is prolonged laterally into the intervertebral foramina, where the dura mater blends with it in producing the increased thickness of the epineurium.

Fig. 666.—Diagram showing Relations of Meninges to Spinal Nerve-roots.



From each side of the cord the pia mater gives off a leaf-like fold, the **ligamentum denticulatum,** which spreads laterally toward the dura mater midway between the lines of attachment of the dorsal and ventral nerve-roots. The outer border of this fold is dentate or scalloped into twenty-one pointed processes, which extend through the arachnoid and are attached to the inner surface of the dura mater. The dentations are usually inserted between the levels of exit of the roots of the spinal nerves, the uppermost one a little above the first cervical nerve and the region where the vertebral artery perforates the dura mater; the lowermost one between the last thoracic and first lumbar nerves, or, between the last two thoracic nerves. The ligamenta denticulata, aided slightly by the septum posticum, serve to hold the spinal cord more or less suspended in the subarachnoid cavity.

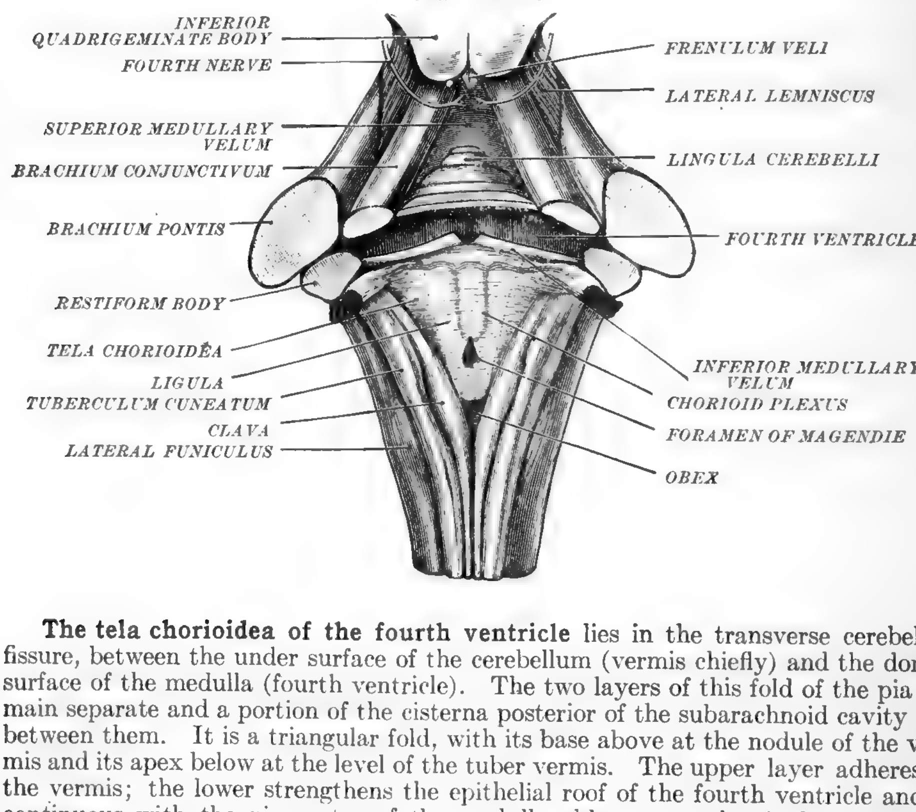
Below, at the sudden, conical termination of the spinal cord in the lumbar portion of the spinal canal, the pia mater is spun out into a thin, tubular filament, the **filum terminale,** which continues downwards into the sac formed by the dura mater about the cauda equina, and at the end fuses with the dura mater in line with the filum of the spinal dura mater (coccygeal ligament) of the outside (figs. 566 and 655).

The cranial pia mater is closely applied to the external surface of the brain, dipping into all the fissures, furrows, and sulci. It is connected with the arachnoid by numerous filaments of the spongy subarachnoid tissue and by the blood-vessels

traversing the subarachnoid cavity. It is also pierced by the cranial nerves, and furnishes them their sheaths, which become continuous with the arachnoid and dura mater. Its *outer surface,* bounding the subarachnoid cavity, is covered by a layer of endothelium. The fibrous portion below is with difficulty separable into two layers of mixed white fibrous and elastic connective tissue, with slightly pigmented connective-tissue cells enmeshed between them. Its *inner surface* sends a large number of fibrous processes into the nervous substance, which blend with the neuroglia and aid in the support of the nervous elements. The larger of these processes accompany the central arterial and venous branches of the rich superficial plexuses of blood-vessels contained in the pia on the surface of the brain. Pieces of the pia when pulled off and placed in water present a flocculent appearance as to their inner surfaces, due to these processes having been pulled out.

The cranial pia mater sends strong, vascular duplications into two of the great fissures of the encephalon; viz., the *transverse cerebellar fissure,* between the cerebellum and the medulla oblongata, and the *transverse cerebral fissure,* between the cerebellum, mesencephalon, and thalamencephalon, and the overhanging cerebral hemispheres. These duplications are spread over the cavities of the fourth and third ventricles, and are known as the *telæ chorioideæ* of these ventricles respectively.

Fig. 667.—Diagram showing Tela Chorioidea of Fourth Ventricle after Removal of Cerebellum.



The tela chorioidea of the fourth ventricle lies in the transverse cerebellar fissure, between the under surface of the cerebellum (vermis chiefly) and the dorsal surface of the medulla (fourth ventricle). The two layers of this fold of the pia remain separate and a portion of the cisterna posterior of the subarachnoid cavity lies between them. It is a triangular fold, with its base above at the nodule of the vermis and its apex below at the level of the tuber vermis. The upper layer adheres to the vermis; the lower strengthens the epithelial roof of the fourth ventricle and is continuous with the pia mater of the medulla oblongata and spinal cord. This lower layer is the tela of the fourth ventricle proper. In roofing over the calamus scriptorius it constitutes the ligula and the obex. A little above the calamus scriptorius the lower layer is pierced by the foramen of Magendie.

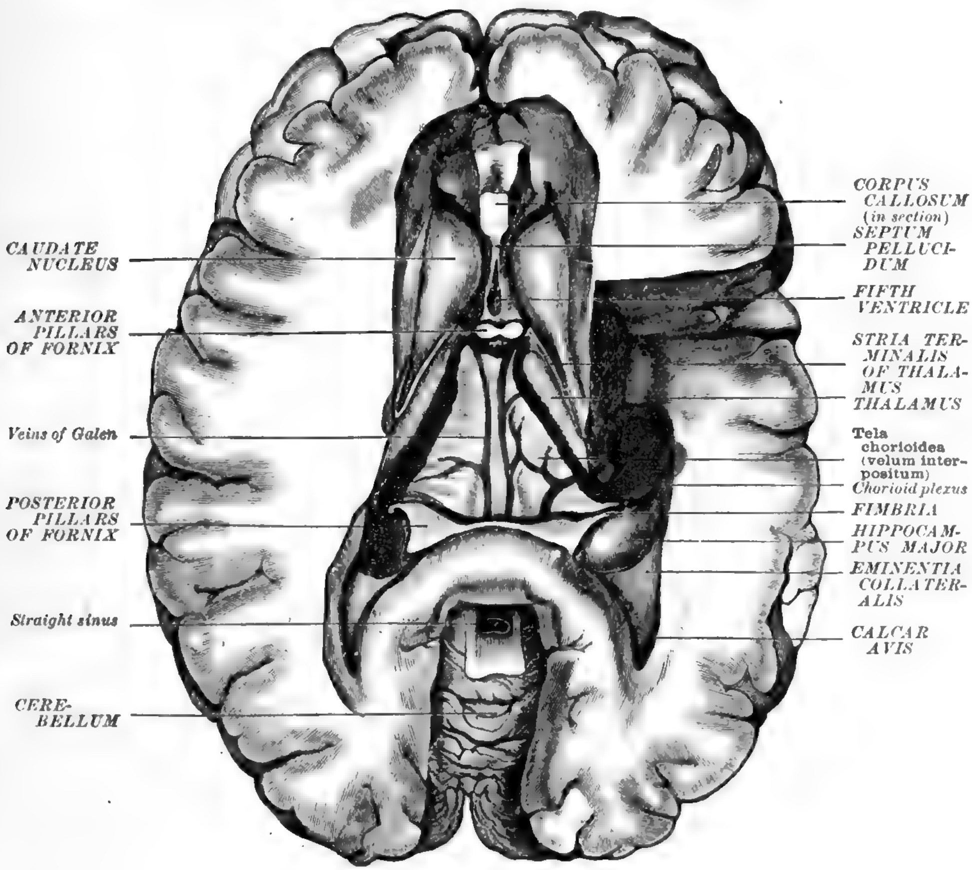
In front of the foramen of Magendie the vessels of the tela chorioidea, which are derived from the posterior inferior cerebellar arteries, form two longitudinal, lobulated strands which invaginate the epithelial roof of the ventricle, one on either side of the mid-line, and project into its cavity. These form the **chorioid plexus of the fourth ventricle.** At the base of the tela the two chorioid plexuses join each other and then turn transversely outwards into the lateral recesses of the ventricle, where they pass behind the restiform bodies and form the '*cornucopiæ.*'

The tela chorioidea of the third ventricle, or **velum interpositum,** is a triangular duplication of the pia mater which extends between the fornix above and the thalami and third ventricle below, and in front ends blindly at the interventricular foramina. In the transverse cerebral fissure the layers of pia forming the tela are separate, the upper being the pia of the under surface of the corpus callosum and continuous with that of the tentorial surfaces of the occipital lobes; the lower being continuous into the pia enfolding the epiphysis, and covering the mesencephalon, anterior medullary velum, and cerebellum. The layers forming the portion of the duplication which roofs over the third ventricle are loosely adherent to each other and form the tela chorioidea proper of that ventricle. The upper surface of this portion is in relation with the fornix and its lower surface, covered by the epithelial chorioid

Fig. 668.—Horizontal Dissection of the Cerebrum showing the Tela Chorioidea of the Third Ventricle.

(From a mounted specimen in the Anatomical Department of Trinity College, Dublin.)

The fornix has been removed to show the tela chorioidea.



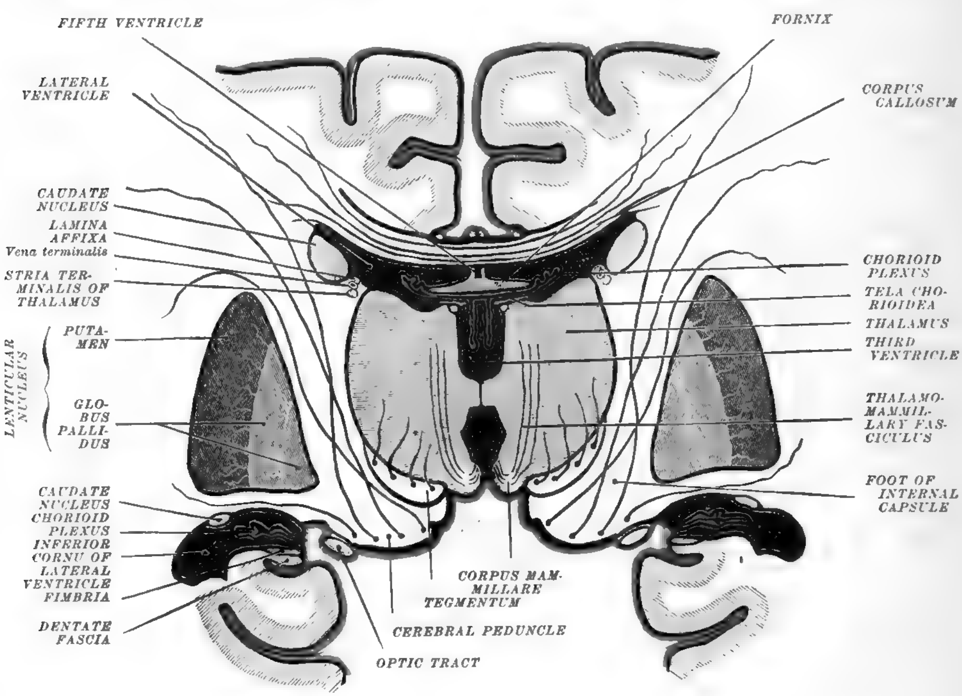
lamina, lies laterally over the superior surfaces of both thalami, and mesially forms the roof of the third ventricle between them. Between the two layers of this portion, and embedded in a small amount of the spongy subarachnoid tissue retained between them, are the two veins of Galen, the internal cerebral veins. Posteriorly these veins unite in the region of the epiphysis to form the single great cerebral vein (*vena cerebri magna*). Anteriorly the veins of Galen receive the veins of the septum pellucidum from each lamina of the septum pellucidum above, and also the terminal vein (vein of corpus striatum), lying in the stria terminalis of the thalamus, empties into them from each side.

The tela chorioidea or velum interpositum extends laterally between the fornix and fimbria above and the stria terminalis of the thalamus below into each lateral

ventricle. Posteriorly the continuation of this lateral extension appears as an invagination into the lateral ventricle through the floor of the chorioid fissure. The blood-vessels of the border projecting into the lateral ventricle are amplified into a plexus which appears as a strip of reddish, lobulated, villus-like processes known as the **chorioid plexus of the lateral ventricle.** The plexus, being in the border of the tela, begins at the interventricular foramen, extends through the body or central portion of the ventricle, and downwards into the inferior cornu. It is most developed at the junction of the body with the inferior cornu, and is there known as the **glomus chorioideum.**

From the under surface of the tela chorioidea of the third ventricle, hanging down on either side of the mid-line into the cavity of the ventricle, are two other longitudinal, lobulated strands of blood-vessels which are the **chorioid plexuses of the third ventricle.** At the anterior end of the third ventricle these two plexuses join with each other and also at the interventricular foramen with the plexus of the lateral ventricle of each side.

Fig. 669.—Diagram of Coronal Section of Cerebrum through Middle of Thalamencephalon showing Relations of Pia Mater Encephali and Chorioid Plexuses of Third and Lateral Ventricles.



The chorioid plexuses of both the ventricles are covered by a layer of epithelium, *epithelial chorioid lamina,* which is but a reflexion of the epithelium lining the cavities throughout. The blood-vessels of the chorioid plexus of the lateral ventricle receive blood by the chorioid artery (a direct branch of the internal carotid), which enters the plexus through the chorioid fissure immediately behind the uncus, and also by the chorioidal branches of the posterior cerebral artery, which supply the plexus of the body of the ventricle. The chorioid plexuses of the third ventricle receive blood chiefly by branches from the superior cerebellar arteries. The greater part of the blood of both plexuses passes out by way of the tortuous chorioid veins, which, at the interventricular foramen, empty into the venæ terminales (veins of the corpus striatum), which, in their turn, go to form the greater part of the veins of Galen. Thence the blood passes by way of the vena cerebri magna into the straight sinus. It is probable that a large part of the cerebro-spinal fluid is derived by diffusion through the walls of the vessels of the chorioid plexuses.

The nerves of the pia mater are probably all for the supply of the numerous blood-vessels in it. They accompany the vessels and form terminal, perivascular plexuses about them. They are chiefly sympathetic, vaso-motor to the smooth muscle in the walls of the vessels. A few fibres of cerebro-spinal origin occur, all of which are, no doubt, of the sensory variety. The nerve supply of the spinal pia mater is derived from the recurrent branches of the spinal nerves.

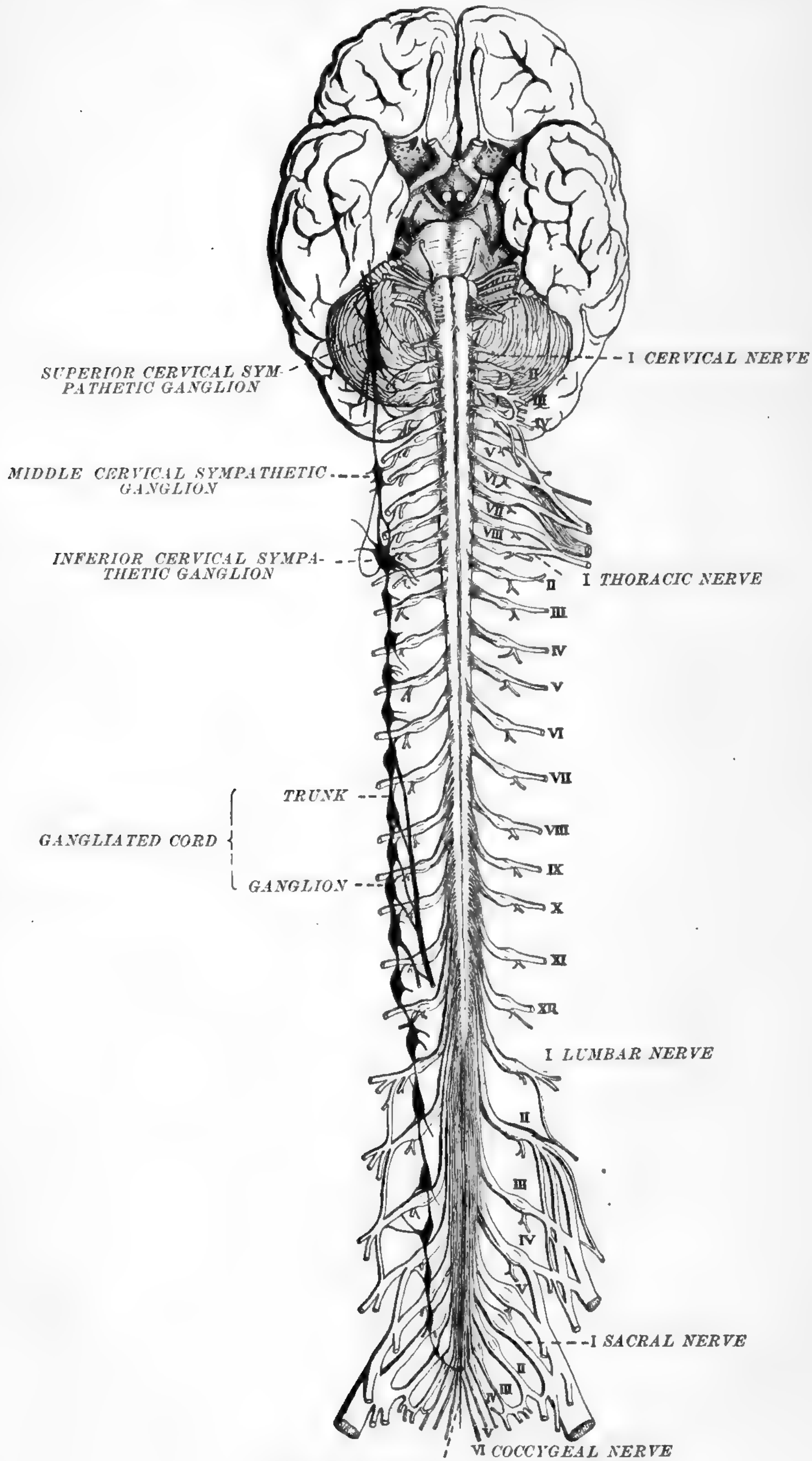
THE PERIPHERAL NERVOUS SYSTEM

The intimate connection and consequent control exercised by the central nervous system over all the tissues and organs of the body is attained through the peripheral nervous system. This system, abundantly attached to the central system, consists of numerous bundles of nerve-fibres which divide and ramify throughout the body, anastomosing with each other and forming various plexuses, large and small. The terminal rami divide and subdivide until the division attains the individual nerve-fibres of which they are composed, and finally the nerve-fibres terminate in relations with their allotted peripheral elements. It is by means of this system that stimuli arising in the peripheral tissues are conveyed to the central system, and that impulses in response are borne from the central system to the peripheral organs. For purposes of description, as well as upon the basis of certain differences in structure, arrangement, and distribution, the peripheral nervous system is separated into two main divisions:—(1) **the cerebro-spinal** and (2) **the sympathetic system.**

Both of these divisions include numerous ganglia or peripheral groups of nerve-cells from which arise a considerable proportion of the fibres forming their nerve-trunks, but neither of the divisions may be considered wholly apart from the central system nor are they separate from each other. The sensory or afferent fibres of the cerebro-spinal nerves pass by way of the afferent nerve-roots into the central system and contribute appreciably to its bulk, and the motor or efferent fibres of these nerves have their cells of origin (nuclei) situated within the confines of the central system. The sympathetic system is intimately associated with the cerebro-spinal, and consequently with the central system—(1) by means of fibres which enter the cerebro-spinal ganglia and convey impulses which enter the central system; (2) by efferent fibres of central origin which course in the nerve-trunks and terminate in the ganglia of the sympathetic system; (3) also, the sympathetic trunks usually contain numerous afferent cerebro-spinal fibres which thus course to their peripheral termination, usually in the so-called 'splanchnic area,' or domain of the sympathetic, in company with the sympathetic fibres. Likewise the peripheral branches of the cerebro-spinal nerves often carry for varying distances numerous sympathetic fibres which are on their way to terminate either in other sympathetic ganglia or upon their allotted tissue-elements.

The following **differences** between the cerebro-spinal and sympathetic systems of nerves may be cited:—(1) The cerebro-spinal nerves are anatomically continuous with the brain and spinal cord; probably no fibres arising in the sympathetic ganglia actually enter the central system. (2) The ganglia of the cerebro-spinal nerves all lie quite near the central axis, in line on either side of it, and at more or less regular intervals; the sympathetic ganglia are scattered throughout the body tissues, are far more numerous and more variable in size, and probably only the larger of them are symmetrical for the two sides of the body. (3) The cerebro-spinal nerves are paired throughout, and the nerves of each pair are symmetrical as to their origin and also, with certain exceptions (notably the vagus), in their course and distribution; most of the larger and more proximal of the sympathetic nerve-trunks are symmetrical for the two sides of the body; many of them are not, and many of the smaller and most of the more peripheral nerves are not paired at all. (4) Even in their finer twigs, the cerebro-spinal nerves of the two sides probably do not anastomose with each other across the mid-line of the body; the sympathetic nerves do so abundantly, especially within the body cavity. (5) The cerebro-spinal nerves are distributed to the ordinary sensory surfaces of the body and the organs of special sense and to the somatic, striated or 'voluntary' muscles of the body; the sympathetic fibres are devoted chiefly to the supply of the so-called involuntary muscles of the body, including the smooth muscle in the walls of the viscera and in the walls of the blood and lymph

FIG. 670.—SHOWING THE RELATION BETWEEN THE CENTRAL AND THE PERIPHERAL NERVOUS SYSTEMS.
(Combination drawing in part after Allen Thompson, from Rauber.)



vascular systems, while some serve as secretory fibres to the glands. (6) Cerebro-spinal nerve-fibres are characterized by well-developed medullary sheaths, making the nerves appear as white strands; most of the sympathetic fibres are non-medullated, some are partially medullated, but none possess as thick medullary sheaths as those of the cerebro-spinal nerves. Thus sympathetic nerves appear as grey strands.

The cerebro-spinal nerves.—There are forty-three pairs of cerebro-spinal nerves, of which thirty-one pairs are attached to the spinal cord (spinal nerves) and twelve pairs to the encephalon (cranial nerves). The spinal nerves are the more primitive and retain the typical character, i.e., each is attached to the spinal cord by two roots, a dorsal or sensory ganglionated root, and a ventral, which is motor, and thus not ganglionated. Most of the cranial nerves have only one root, which in some cases corresponds to a dorsal root and therefore has a ganglion, and in other cases corresponds, physiologically at least, to a ventral root of a spinal nerve. Among other differences, the fibres of the first cranial nerve, for example, do not collect to form a distinct nerve-trunk. On account, therefore, of their more typical characters, it is convenient to consider the spinal nerves first.

THE SPINAL NERVES

The spinal nerves are arranged in pairs, the nerves of each pair being symmetrical in their attachment to either side of their respective segment of the spinal cord, and, in general, symmetrical in their course and distribution. There are usually thirty-one pairs of functional spinal nerves. For purposes of description these are topographically separated into *eight* pairs of *cervical* nerves, *twelve* pairs of *thoracic* nerves, *five* pairs of *lumbar*, *five* pairs of *sacral*, and *one* pair of *coccygeal* nerves. Occasionally the coccygeal or thirty-first pair is practically wanting, while, on the other hand, there may be frequently found small filaments representing one or even two additional pairs of coccygeal nerves below the thirty-first pair. These **rudimentary coccygeal nerves** are probably not functional. They never pass outside the vertebral canal, and often even remain within the tubular portion of the filum terminale. There sometimes occurs an increase in the number of vertebræ in the vertebral column and in such cases there is always a corresponding increase in the number of the spinal nerves.

Origin and attachment.—Each spinal nerve is attached to the spinal cord by two roots:—a sensory or afferent **dorsal root** and a motor or efferent **ventral root.** Each dorsal root has interposed in its course an ovoid mass of nerve-cells, the **spinal ganglion,** and the nerve-fibres forming the root arise from the cells of this ganglion and are thus of peripheral origin. The fibres composing the ventral root, on the other hand, are of central origin; they arise from the large motor cells of the ventral horn of the grey column within the spinal cord. Each dorsal root-fibre upon leaving its cell of origin pursues a short tortuous course within the spinal ganglion and then undergoes a T-shaped bifurcation, one product of which passes towards the periphery, where it terminates for the collection of sensations and is known as the *peripheral branch*, or, since it conveys impulses towards the cell-body, the *dendrite* of the spinal ganglion neurone. The other product of the bifurcation, the *central branch*, passes into the spinal cord and in its course towards the cord contributes to form the dorsal root proper.

The central branches, upon emerging from the spinal ganglia, form a single compact bundle at first, which passes through the dura mater of the spinal cord and then breaks up into a series of root-filaments (**fila radicularia**). These thread-like bundles of fibres spread out vertically in a fan-like manner and enter the cord in a direct linear series along its postero-lateral sulcus. The fibres of the ventral root emerge from the cord in a series of more finely divided root filaments, which, unlike the entering filaments of the dorsal root, are not arranged in direct linear series, but make their exit over a strip of the ventro-lateral aspect of the cord in some places as much as two millimetres wide.

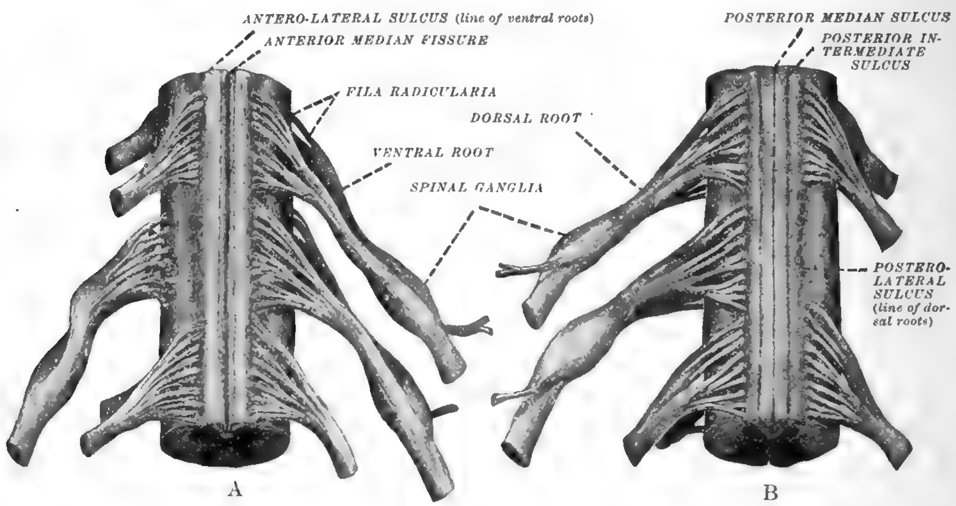
As they enter the spinal cord the fibres of the dorsal roots undergo a Y-shaped division, both products of which course in the cord longitudinally, an ascending and a descending branch. The descending or caudad branches are shorter than the ascending, and soon enter and terminate about the cells within the grey column of the cord, forming either associational, commissural, or reflex connections, or about cells whose fibres form cerebellar connections. The ascending or cephalad branches are either short, intermediate, or long. The short and intermediate

branches are similar in function to the descending branches, save that they become associated with the grey substance of segments of the cord above rather than below the level of their entrance. The long branches convey impulses destined for the structures of the brain, and pass upwards in the fasciculus gracilis or fasciculus cuneatus of the cord, and terminate in the nuclei of these fasciculi in the medulla oblongata (figs. 646 and 648).

Aberrant spinal ganglia.—In serial sections on either side of the spinal ganglion of a nerve there may often be found outlying cells either scattered or in groups of sufficient size to be called small ganglia. Such are more often found in the dorsal roots of the lumbar and sacral nerves. These cells are nothing more than spinal ganglion-cells displaced in the growth processes, and have the same nature and function as those in the ganglion. In some animals occasional cells very rarely have been found in the outer portion of the ventral root. These probably represent afferent fibres which enter the cord by way of the ventral root. Likewise, especially in the birds and amphibia, it has been shown that occasional efferent fibres may pass from the grey substance of the cord to the periphery by way of the dorsal instead of the ventral root.

Relative size of the roots.—The sensory or dorsal root is larger than the ventral root, indicating that the sensory area to be supplied is greater and perhaps more abundantly innervated than the area requiring motor fibres. It has been shown that in the entire thirty-one spinal nerves of one side of the body of man the dorsal root fibres number 653,627, while all the corresponding ventral roots contain but 233,700 fibres, a ratio of 3.2 : 1. (Ingbert.) In the increase in the size of the nerves for the

FIG. 671.—DORSAL AND VENTRAL VIEWS OF SPINAL CORD SHOWING MANNER OF ATTACHMENT OF DORSAL AND VENTRAL ROOTS.



supply of the limbs the gain of dorsal root or sensory fibres is far greater than the gain of ventral root-fibres. The first cervical or the sub-occipital nerve is always an exception to the rule; its dorsal root is always smaller than its ventral, and in rare cases may be rudimentary or entirely absent. The spinal ganglion and, therefore, the sensory root of the coccygeal nerve, is also quite frequently absent.

The dorsal and ventral root-fibres of each spinal nerve proceed outwards from their segment of attachment to the spinal cord, pierce the pia mater and arachnoid, collect to form their respective roots, and pass into their respective intervertebral foramina. On the immediate peripheral side of the spinal ganglion the two roots blend, giving origin to the thus mixed **nerve-trunk.** As the trunk, the sensory and motor fibres make their exit from the vertebral canal through the intervertebral foramen.

Relation to the meninges.—The root filaments of each nerve receive connective-tissue support from the pia mater and arachnoid in passing through them. In the arachnoid cavity they become assembled into their respective nerve-roots, and the roots, closely approaching each other, pass into the dura mater, from which they receive separate sheaths at first, but at the peripheral side of the ganglion these sheaths blend into one, which, with the subsequent blending of the roots, becomes the sheath or epineurium of the nerve trunk. By means of the sheaths derived from the

meninges, especially the dura, the nerve-roots and the trunk are attached to the periosteum of the margins of the intervertebral foramina and thus are enabled to give some lateral support to the spinal cord in the upper portion of the canal. The majority of the spinal ganglia lie in the intervertebral foramina, closely ensheathed, and thus outside the actual sac or cavity of the dura mater. The ganglia of the last lumbar and first four sacral nerves lie inside the vertebral canal, but since the sheath derived from the dura mater closely adheres to them, they are still outside the sac of the dura mater. The ganglia of the last sacral and of the coccygeal nerves (when present) lie in tubular extensions of the sub-dural cavity, and thus not only within the vertebral canal, but actually within the sac of the dura mater. The trunk of the first cervical nerve is assembled within the sac of the dura mater, and, therefore, the spinal ganglion of this nerve, when present, may lie within the sac.

Course and direction of emergence.—Invested with the connective-tissue sheath derived from the meninges, each spinal nerve emerges from the vertebral canal through the intervertebral foramen below the corresponding vertebra, and in relation with the spinal rami of the arteries and veins associated with the blood supply of the given localities of the spinal cord. The first cervical nerve does not pass outwards in an intervertebral foramen proper, but between the occipital bone and the posterior arch of the atlas and beneath the vertebral artery. Thus the eighth or last cervical nerve emerges between the seventh cervical and the first thoracic vertebra.

The first and second pairs of cervical nerves pass out of the vertebral canal almost at right angles to the levels of their attachment to the spinal cord. During the early periods of development the level of exit of each pair of spinal nerves is opposite the level of its attachment to the cord, but, owing to the fact that in the later periods the vertebral column grows more rapidly than the cord and increases considerably in length after the cord has practically ceased growing, all the spinal nerves, with the exception of the first two, pass downwards as well as outwards. The obliquity of their course from the level of attachment to the level of exit increases progressively from above downwards, and, as the cord terminates at the level of the second lumbar vertebra, the roots of the lower lumbar and of the sacral nerves pass at first vertically downwards within the dura mater, and form around the filum terminale a tapering sheaf of nerve-roots, the **cauda equina** (horse's tail) (fig. 566, p. 759).

Topography of attachment.—The relations between the levels of attachment of the spinal nerves to the cord and the spinous processes of the vertebræ situated opposite these levels have been investigated by Nuhn and by Reid. The following table compiled by Reid gives the extreme limits of attachment as observed in six subjects.

TABLE OF TOPOGRAPHY OF ATTACHMENT OF SPINAL NERVES. (Reid.)

(A) signifies the highest level at which the root filaments of a given nerve are attached to the cord, and (B) the lowest level observed. For example, the root filaments of the sixth thoracic nerve *may* be attached as high as the lower border of the spinous process of the second thoracic vertebra, or some may be attached as low as the upper border of the spinous process of the fifth thoracic vertebra, but in a given subject they do not necessarily extend either as high or as low as either of the levels indicated.

Nerves		
Second cervical	(A)	A little above the posterior arch of atlas.
	(B)	Midway between posterior arch of atlas and spine of axis.
Third "	(A)	A little below posterior arch of atlas.
	(B)	Junction of upper two-thirds and lower third of spine of axis.
Fourth "	(A)	Just below upper border of spine of axis.
	(B)	Middle of spine of third cervical vertebra.
Fifth "	(A)	Just below lower border of spine of axis.
	(B)	Just below lower border of spine of fourth cervical vertebra.
Sixth "	(A)	Lower border of spine of third cervical vertebra.
	(B)	Lower border of spine of fifth cervical vertebra.
Seventh "	(A)	Just below upper border of spine of fourth cervical vertebra.
	(B)	Just above lower border of spine of sixth cervical vertebra.
Eighth "	(A)	Upper border of spine of fifth cervical vertebra.
	(B)	Upper border of spine of seventh cervical vertebra.
First thoracic	(A)	Midway between spines of fifth cervical and sixth cervical vertebra.
	(B)	Junction of upper two-thirds and lower third of interval between seventh cervical and first thoracic vertebra.
Second "	(A)	Lower border of spine of sixth cervical vertebra.
	(B)	Just above lower border of spine of first thoracic vertebra.

Nerves	
Third thoracic	(A) Just above middle of spine of seventh cervical vertebra. (B) Lower border of spine of second thoracic vertebra.
Fourth "	(A) Just below upper border of spine of first thoracic vertebra. (B) Junction of upper third and lower two-thirds of spine of third thoracic vertebra.
Fifth "	(A) Upper border of spine of second thoracic vertebra. (B) Junction of upper quarter and lower three-quarters of spine of fourth thoracic vertebra.
Sixth "	(A) Lower border of spine of second thoracic vertebra. (B) Just below upper border of spine of fifth thoracic vertebra.
Seventh "	(A) Junction of upper third and lower two-thirds of spine of fourth thoracic vertebra. (B) Just above lower border of spine of fifth thoracic vertebra.
Eighth "	(A) Junction of upper two-thirds and lower third of interval between spines of fourth thoracic and fifth thoracic vertebra. (B) Junction of upper quarter and lower three-quarters of spine of sixth thoracic vertebra.
Ninth "	(A) Midway between spines of fifth thoracic and sixth thoracic vertebra. (B) Upper border of spine of seventh thoracic vertebra.
Tenth "	(A) Midway between spines of sixth thoracic and seventh thoracic vertebra. (B) Middle of the spine of eighth thoracic vertebra.
Eleventh "	(A) Junction of upper quarter and lower three-quarters of spine of seventh thoracic vertebra. (B) Just above spine of ninth thoracic vertebra.
Twelfth "	(A) Junction of upper quarter and lower three-quarters of spine of eighth thoracic vertebra. (B) Just below spine of ninth thoracic vertebra.
First lumbar	(A) Midway between spines of eighth thoracic and ninth thoracic vertebræ. (B) Lower border of spine of tenth thoracic vertebra.
Second "	(A) Middle of spine of ninth thoracic vertebra. (B) Junction of upper third and lower two-thirds of spine of eleventh thoracic vertebra.
Third "	(A) Middle of spine of tenth thoracic vertebra. (B) Just below spine of eleventh thoracic vertebra.
Fourth "	(A) Just below spine of tenth thoracic vertebra. (B) Junction of upper quarter and lower three-quarters of spine of twelfth thoracic vertebra.
Fifth "	(A) Junction of upper third and lower two-thirds of spine of eleventh thoracic vertebra. (B) Middle of spine of twelfth thoracic vertebra.
First sacral	(A) Just above lower border of spine of eleventh thoracic vertebra.
Fifth "	(B) Lower border of spine of first lumbar vertebra.
Coccygeal	(A) Lower border of spine of first lumbar vertebra. (B) Just below upper border of spine of second lumbar vertebra.

Relative size of the nerves.—The size of the different spinal nerves varies greatly. Just as the spinal cord shows marked enlargements in the cervical and lumbar regions necessitated by the greater amount of innervation required of these regions for the structures of the upper and lower limbs, so the nerves attached to these regions are considerably larger than elsewhere. The smaller nerves are found in the two extremities of the series and in the mid-thoracic region. The smallest nerve is the coccygeal, and the next in order of size are the lower sacral and the first two or three cervical nerves. The largest nerves are those which contribute most to the great nerve-trunks for the innervation of the skin and muscles of the limbs:—the lower cervical and first thoracic for the upper limbs and the lower lumbar and first sacral for the lower limbs. The nerves gradually increase in the series in passing from the smaller towards the larger.

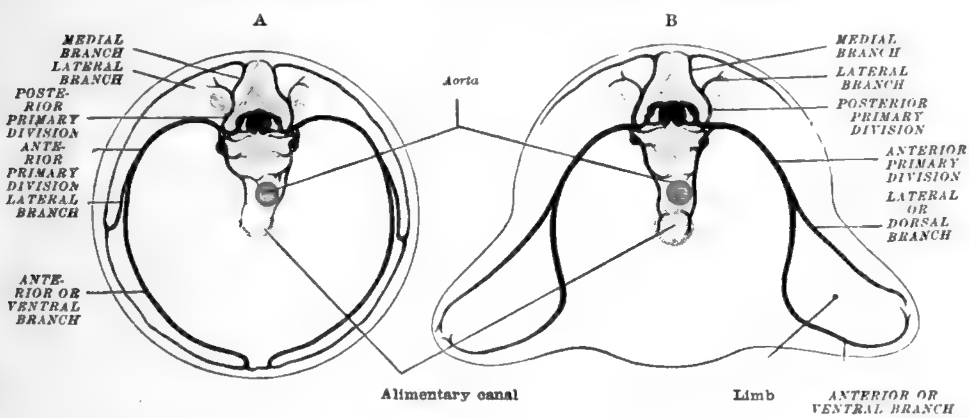
The primary divisions of the nerve-trunk.—A typical spinal nerve (middle thoracic, for example), just as it emerges from the intervertebral foramen, divides into four branches:—the two large primary divisions; viz., the **posterior primary division** (*ramus posterior*) and the **anterior primary division** (*ramus anterior*); third, the small **ramus communicans,** by which it is connected with the sympathetic; and fourth, the smaller, **ramus meningeus** (*recurrent branch*), which immediately turns centralwards for the innervation of the membranes of the spinal cord.

In general, the **posterior primary division** passes dorsalwards between the arches or transverse processes of the two adjacent vertebræ in relation with the anterior costo-transverse ligament, and then divides (with the exception of the first cervical,

the fourth and fifth thoracic, and the coccygeal nerves) into a **medial (internal) branch** and a **lateral (external) branch.** The medial branch turns inwards towards the spinous processes of the vertebræ, and supplies the bones and joints and the muscles about them, and may or may not supply the skin overlying them. The lateral branch turns outwards and dorsalwards and also supplies the adjacent muscles and bones, and, if the medial branch has not supplied the overlying skin, it terminates in cutaneous twigs. In the upper half of the spinal nerves the medial branches supply the skin; in the lower half, it is the lateral branches which do so. Both branches of almost all the posterior divisions, especially those of the lower nerves, show a tendency to run caudalwards and thus are distributed to muscles and skin below the levels of their respective intervertebral foramina. They never supply the muscles of the limbs, though their cutaneous distribution extends upon the buttock, the shoulder, and the skin of the back of the head as far upwards as the vertex. The posterior primary divisions, with the exception of those of the first three cervical nerves, are much smaller than the anterior primary divisions.

As their mixed function suggests, the posterior primary divisions contain both nerve-fibres from the ventral roots and peripheral fibres (dendrites) arising from the spinal ganglion-cells. If the nerve-trunk on the immediate peripheral side of the spinal ganglion be teased, bundles of ventral root-fibres may be seen crossing the trunk obliquely to enter the posterior division, and fibres from the spinal

FIG. 672.—DIAGRAMS ILLUSTRATING THE ORIGIN AND DISTRIBUTION OF A TYPICAL SPINAL NERVE.
A, in thoracic region; B, in region of a limb (highly schematic).



ganglion may also be traced into it. Also a few sympathetic fibres, derived chiefly by way of the ramus communicans, are known to course in it for distribution in the walls of the blood-vessels, etc., of the area it supplies.

The anterior primary divisions run outwards and ventralwards. With the exception of the first three cervical nerves, they are larger than the posterior primary divisions, and appear as direct continuations of the nerve-trunks. Only in case of most of the thoracic nerves do they remain independent in their course. In these they run outwards and ventralwards in the body-wall. In general, these divisions supply the lateral and ventral parts of the body, the limbs, and the perineum. In the cervical, lumbar, and sacral regions they lose their anatomical identity by dividing, subdividing, and anastomosing with each other so as to give rise to the three great cerebro-spinal plexuses of the body—the **cervical,** the **brachial,** and the **lumbo-sacral plexuses.** The majority of the thoracic nerves retain the typical or primitive character in both their anterior and posterior primary divisions. In them the anterior division (intercostal nerve) divides into a **lateral** or dorsal and an **anterior** or ventral branch, both of which subdivide. The lateral branch is chiefly cutaneous; it pierces the superficial muscles and, in the subcutaneous connective tissue, divides into a smaller posterior and a larger anterior ramus, which respectively supply the skin of the sides and the lateral part of the ventral surface of the body. The anterior branch continues ventralwards in the body-wall, giving off twigs along its course to the adjacent muscles and bones, and, as it approaches the ventral mid-

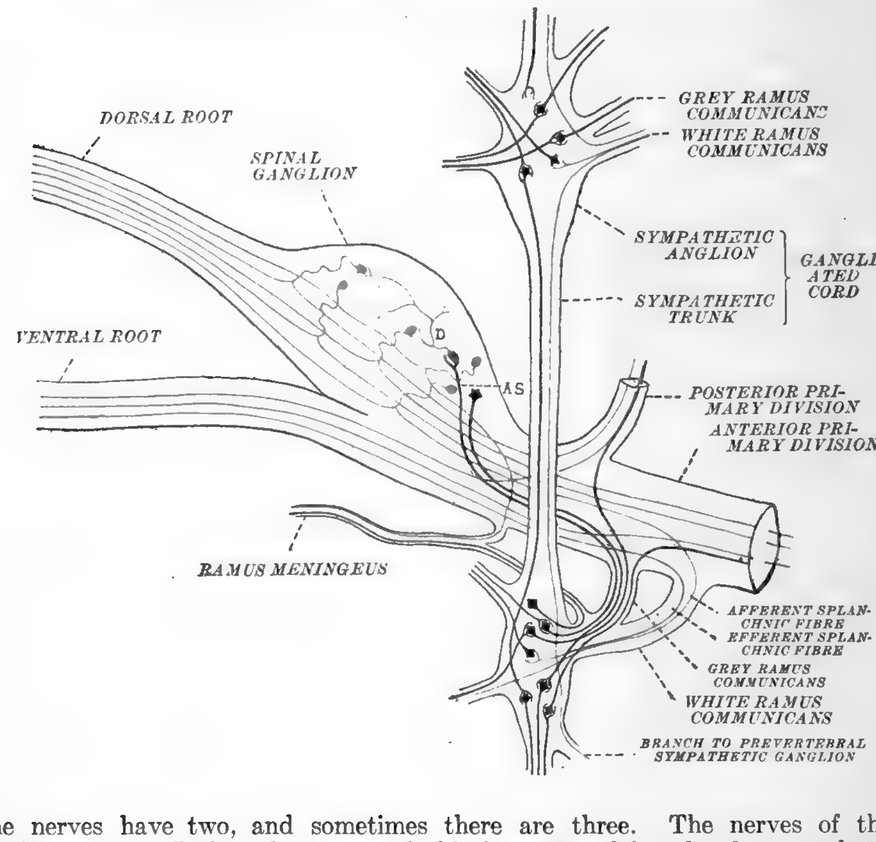
line of the body, it turns sharply outwards and sends rami medianwards and lateralwards to supply the skin of the ventral aspect of the body. In the region of the limbs the typical arrangement is interfered with in that what corresponds to the lateral and anterior branches of the division are carried out into the limbs for the skin and muscles there, instead of supplying the lateral and ventral parts of the body-wall.

Nerve-fibres arising in the spinal ganglion and fibres from the ventral or motor root pass directly from the nerve-trunk into the anterior primary division of the spinal nerve. This division also receives sympathetic nerve-fibres by way of the ramus communicans. These latter accompany the division and are distributed to their allotted elements in the territory it supplies.

The rami communicantes are small, short, thread-like branches by which the nerve-trunks are connected with the nearest ganglion of the vertically running gangliated cord of the sympathetic (sympathetic trunk). The trunk or anterior primary division of every spinal nerve has at least one of these; most

FIG. 673.—DIAGRAM ILLUSTRATING THE ORIGIN OF THE COMPONENT NERVE-FIBRES OF THE PRIMARY DIVISIONS OF A TYPICAL SPINAL NERVE.

AS, Afferent sympathetic fibre; D, Dogiel spinal ganglion-cell of type II.



of the nerves have two, and sometimes there are three. The nerves of the cervical region usually have but one, and this is composed largely of sympathetic fibres (grey ramus). Where there are two, one usually contains medullated fibres sufficient to give it a whiter appearance (white ramus). In the upper cervical and in the sacral regions one sympathetic ganglion may be connected with two or more spinal nerves, and sometimes one nerve is connected with two ganglia. The rami communicantes of the spinal nerves are equivalent to the communicating rami connecting certain of the cranial nerves with the sympathetic system (trigeminus, glosso-pharyngeus, vagus). The medullated fibres of the rami and, therefore, the white rami consist chiefly of fibres from the spinal nerves, viz., fibres from the spinal ganglion-cells which enter and course to their distribution through the sympathetic nerves, **splanchnic afferent fibres,** and fibres from the ventral roots of the spinal nerves which terminate in the sympathetic ganglia, **splanchnic efferent**

fibres. Thus the white rami have been termed the **visceral divisions** of the spinal nerves. The grey rami consist chiefly of sympathetic fibres, most of which are non-medullated or partially medullated, and which course to their distribution by way of the spinal nerves. Some of the sympathetic fibres terminate in the spinal ganglion, **afferent sympathetic fibres** (fig. 673). The usual absence of white rami communicantes from the cervical nerves is explained on the grounds—(1) that probably relatively few efferent splanchnic fibres are given to the sympathetic from this region of the cord; (2) that many of the efferent splanchnic fibres which do arise from this region of the cord probably join the rootlets of the spinal accessory or eleventh cranial nerve and pass to the sympathetic system through the trunk of this nerve, and through the vagus with which it anastomoses; and (3) that such of these fibres as are given off from the lower segments of this region, descend the cord and pass out by way of the upper thoracic nerves which give very evident white rami to the sympathetic.

The meningeal or **recurrent branch** (figs. 672, 673, and 685) is very small and variable, and is seldom seen in ordinary dissections. It is given off from the nerve-trunk just before its anterior and posterior primary divisions are formed. It consists of a few peripheral branches of spinal ganglion-cells (sensory fibres) which leave the nerve-trunk and re-enter the vertebral canal for the innervation of the meninges, and which are joined by a twig from the grey ramus or directly from the nearest sympathetic ganglion (vaso-motor fibres). There is considerable evidence, both physiological and anatomical, obtained chiefly from the animals, which shows that at times certain of the peripheral spinal ganglion or sensory fibres may turn backwards in the nerve-trunk and pass to the meninges within the ventral root instead of contributing to a recurrent branch. The occurrence of such fibres in the ventral root explains the physiological phenomenon known as '*recurrent sensibility.*' Likewise, sympathetic fibres entering the trunk through the grey ramus may pass to the meninges by way of the ventral root, and at times the recurrent branch is probably absent altogether, its place being taken entirely by the meningeal fibres passing in the ventral root.

Areas of distribution of the spinal nerves.—Both the posterior and anterior primary divisions divide and subdivide repeatedly, and their component fibres are distributed to areas of the body more or less constant for the nerves of each pair, but the distribution of the different nerves is very variable. Corresponding to their attachment, each to a given segment of the spinal cord, the nerves have primarily a segmental distribution, but, owing to the developmental changes and displacement of parts during the growth of the body, the segmental distribution becomes greatly obscured and in some nerves practically obliterated. Naturally it is more retained by the nerves supplying the trunk than by those contributing to the innervation of the limbs and head, and the areas supplied by the posterior primary divisions are less disturbed than those supplied by the anterior. The segmental areas of cutaneous distribution of the posterior divisions are more evident than the areas of muscle supplied by these divisions, from the fact that the segmental myotomes from which the dorsal muscles arise fuse together and overlap each other considerably during development. No nerve has a definitely prescribed area of distribution, cutaneous or muscular, for its area is always considerably overlapped by the areas of the nerves adjacent to it. The mid-thoracic nerves more nearly supply a definitely prescribed belt of the body.

POSTERIOR PRIMARY DIVISIONS

The posterior primary divisions of the spinal nerves spring from the trunks immediately outside the intervertebral foramina, and they pass backwards between the adjacent transverse processes. With the exceptions of the first and second cervical nerves they are smaller than the corresponding anterior primary divisions, and after passing between the transverse processes into the region of the back they divide into medial and lateral branches. This division, however, does not occur in the cases of the first cervical, the last two sacral, and the coccygeal nerves.

Cervical Nerves

The **posterior primary division of the first cervical** or **sub-occipital nerve** is larger than the anterior primary division. It springs from the trunk, between

the vertebral artery and the posterior arch of the atlas, passes backwards into the sub-occipital triangle, and breaks up into branches which supply the superior oblique, the inferior oblique, and the rectus capitis posterior major muscles, which form the lateral boundaries of the triangle. It also gives a branch across the posterior surface of the rectus capitis posterior major to the rectus capitis posterior minor, and a branch to the semispinalis capitis (complexus) in the roof of the triangle. It communicates with the medial branch of the posterior primary division of the second cervical nerve, either through or over the inferior oblique muscle, and it occasionally gives a cutaneous branch to the skin of the upper part of the back of the neck and the lower part of the scalp.

The **posterior primary division of the second cervical nerve** is the largest posterior division of all. It divides into a small lateral branch and a very large medial branch. The **lateral branch** gives a twig to the inferior oblique and terminates in branches which supply the splenius and longissimus capitis (trachelo-mastoid) muscles. The **medial branch** is the **greater occipital nerve.** It turns around the lower border of the inferior oblique, crosses the sub-occipital triangle obliquely, pierces the semispinalis capitis (complexus), the tendon of the trapezius, and the deep cervical fascia, passing through the latter immediately below the superior nuchal line of the occipital bone, and it divides into several terminal branches which ramify in the superficial fascia of the scalp. It gives one or two motor twigs to the semispinalis capitis (complexus), and its terminal branches which are accompanied by branches of the occipital artery supply the skin of the scalp, above the superior nuchal line, as far forwards as the vertex. Occasionally one branch reaches the pinna and supplies the skin on the upper part of its medial aspect. As it turns around the inferior oblique it gives communicating branches to the medial branches of the posterior primary divisions of the first and third cervical nerves, and in this manner a small looped plexus is formed beneath the semispinalis capitis (complexus) muscle, the *posterior cervical plexus of Cruveilhier.*

The **posterior primary branches of the third, fourth, and fifth cervical nerves** divide at the outer border of the semispinalis colli into medial and lateral branches. The **medial branches** of the third, fourth, and fifth nerves run backwards between the semispinalis colli and capitis (complexus), supplying both muscles. Then, after passing backwards between the semispinalis capitis and the ligamentum nuchæ, they pierce the origin of the trapezius and supply the skin of the back of the neck. The greater part of the medial branch of the third nerve, which runs upwards in the superficial fascia to the scalp, is called the **third** or **smallest occipital nerve;** it communicates with the greater occipital nerve, and it supplies the skin of the upper part of the back of the neck, near the middle line, and the skin of the scalp in the region of the external occipital protuberance.

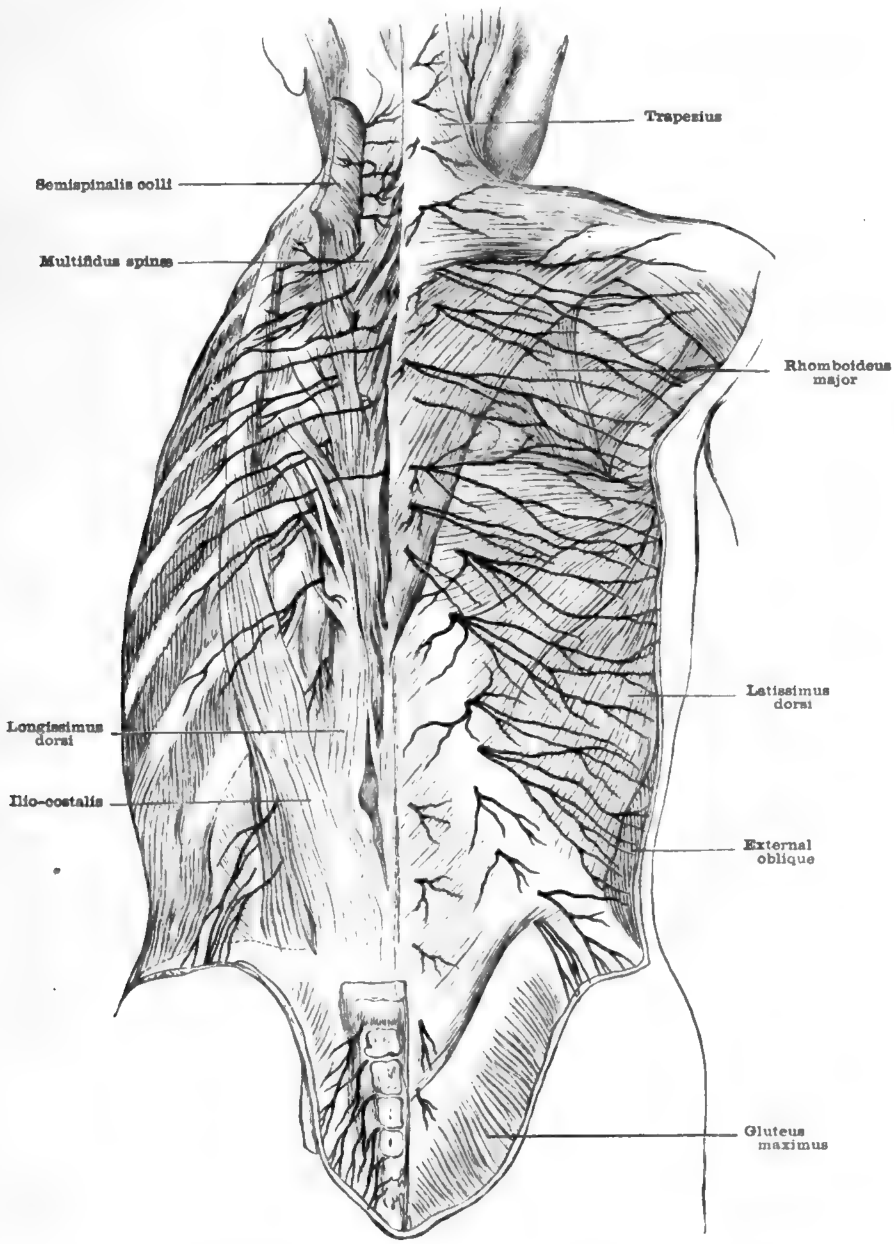
The **medial branches** of the posterior primary divisions of the sixth, seventh, and eighth cervical nerves pass to the median side of the semispinalis colli, between it and the subjacent multifidus spinæ, and they end in the neighbouring muscles. The **lateral branches of the posterior primary divisions of the last five cervical nerves** are small and they are distributed to the longissimus capitis (trachelo-mastoid), the ilio-costalis cervicis (cervicalis ascendens), the longissimus cervicis (transversalis cervicis), the semispinalis capitis (complexus), and the splenius muscles.

Thoracic Nerves

The **posterior primary divisions of all the thoracic nerves** divide into medial and lateral branches as soon as they enter the vertebral groove. The **medial branches of the upper six thoracic nerves** pass backwards between the semispinalis dorsi and the multifidus spinæ; they supply the spinalis dorsi, the semispinalis dorsi, the multifidus spinæ, the rotatores spinæ, the intertransversales, and the interspinales muscles, and they end in cutaneous branches which, after piercing the trapezius, turn lateralwards in the superficial fascia of the back, and supply the skin as far as the middle of the scapula. The cutaneous branch of the second nerve is the largest; it can be traced lateralwards as far as the acromion process. The **medial branches of the lower six thoracic nerves** run dorsalwards, between the longissimus dorsi and the multifidus spinæ; they chiefly end in twigs to the adjacent muscles, but not uncommonly they give small cutaneous twigs which pierce the latissimus dorsi and the trapezius and end in the skin near the mid-line of the back.

The lateral branches of the upper six thoracic nerves pass between the longissimus dorsi and the ilio-costalis dorsi (accessorius) and end in those muscles, but the **lateral branches of the six lower nerves** are longer; they pass into the interval between the longissimus dorsi and the ilio-costalis dorsi and give branches to them, and then they pierce the latissimus dorsi and are distributed to the skin of the lower and lateral part of the back.

Fig. 674.—Distribution of the Posterior Primary Divisions of the Spinal Nerves. (Henle.)



Lumbar Nerves

The **medial branches** of the posterior primary divisions of all the lumbar nerves end in the multifidus spinæ and those of the three lower nerves send very small branches to the skin of the sacral region.

The **lateral branches of the upper three nerves** pass obliquely lateralwards, supplying twigs to the adjacent muscles, pierce the posterior layer of the lumbar aponeurosis at the outer border of the sacro-spinalis (erector spinæ) and enter the subcutaneous tissue. They are, for the most part, cutaneous, forming the **superior clunial nerves,** which cross the crest of the ilium and pass downwards to occupy different planes in the thick superficial fascia which covers the upper part of the gluteus medius. The branch from the first nerve is comparatively small, and occupies the most superficial plane. The second occupies an intermediate position. The branch from the third nerve is the largest of the three, and occupies the lowest position; it distributes branches over the gluteus maximus as far as the great trochanter. The three nerves anastomose with one another and also with the cutaneous branches from the posterior primary divisions of the two upper sacral nerves. The **lateral branch of the fourth lumbar nerve** is of small size and ends in the lower part of the sacro-spinalis (erector spinæ). The **lateral branch of the fifth lumbar** is distributed to the sacro-spinalis and communicates with the first sacral nerve.

Sacral Nerves

The posterior primary divisions of the upper four sacral nerves escape from the vertebral canal by passing through the posterior sacral foramina; those of the fifth sacral nerve pass out through the hiatus sacralis between the posterior sacro-coccygeal ligaments. The upper three sacral nerves divide in the ordinary manner into medial and lateral branches; the lower two sacral nerves remain undivided.

The **medial branches** of the upper three sacral nerves are of small size, and are distributed to the multifidus spinæ. The **lateral branches** anastomose with one another and with the external branch of the last lumbar nerve, forming loops on the posterior surface of the sacrum from which branches proceed to the posterior surface of the sacro-tuberous (great sacro-sciatic) ligament, where they anastomose and form a second series of loops, and from these two or three branches are given off. These branches pierce the gluteus maximus and come to the surface of that muscle in a line between the posterior superior spine of the ilium and the tip of the coccyx. Then, as the **middle clunial nerves,** they are distributed to the integument over the inner part of the gluteus maximus, and communicate, in their course through the superficial fascia, with the posterior branches of the lumbar nerves.

The posterior divisions of the **lower two sacral nerves** unite with one another, with the posterior branch of the third sacral, and with the coccygeal nerve, forming loops from which twigs pass to the integument over the lower end of the coccyx.

The **posterior division of the coccygeal nerve** is also undivided. It separates from the anterior division in the sacral canal and emerges through the hiatus sacralis, pierces the ligaments which close the lower part of that canal, receives a communication from the posterior division of the last sacral nerve, and ends in the skin over the back of the coccyx.

ANTERIOR PRIMARY DIVISIONS

The anterior primary divisions of the spinal nerves, with the exceptions of the first and second cervical nerves, are larger than the posterior primary divisions, and each is joined near its origin by a grey ramus communicans from the sympathetic gangliated cord (figs. 675, 676, 685). Beginning with the first or second thoracic nerve and ending with the second or third lumbar nerve, each anterior division sends to the gangliated cord a white ramus communicans. The same is true of the second and third or of the third and fourth sacral nerves. These white rami are appropriately designated the **visceral branches** of the spinal nerves. The anterior primary divisions of the cervical, lumbar, sacral, and coccygeal nerves unite with one another to form plexuses, but the anterior primary divisions of the thoracic nerves, except the first and last, remain separate, pursue independent courses, and each divides, in a typical manner, into a lateral and an anterior or ventral branch. The separation of the anterior primary division into lateral and anterior branches is not confined to the thoracic nerves; it occurs also in the lower cervical, the lumbar, and the sacral nerves, but such a division cannot be clearly distinguished either in the upper cervical nerves, or in the coccygeal nerve.

Cervical Nerves

The anterior primary divisions of the **upper four cervical nerves** unite to form the **cervical plexus,** and each receives a communicating branch from the superior cervical sympathetic ganglion. The anterior divisions of the **lower four cervical nerves** are joined by the greater part of the first thoracic nerve and they unite to form the **brachial plexus** (figs. 675, 678, 679). The fifth and sixth cervical nerves receive communicating branches from the middle cervical sympathetic ganglion, and the seventh and eighth from the inferior cervical ganglion, while the first thoracic nerve is always connected with the first thoracic sympathetic ganglion by a grey ramus (figs. 675 and 718) and in most cases also by a white ramus communicans.

THE CERVICAL PLEXUS

The cervical plexus (figs. 675 and 676) is formed by the anterior primary divisions of the upper four cervical nerves which constitute the roots of the plexus. It lies in the upper part of the side of the neck, under cover of the sterno-mastoid, and upon the levator scapulæ and the scalenus medius. It is a looped plexus, consisting of three loops. The convexity of the upper loop is turned forwards, and the convexities of the lower two loops are directed backwards.

As the anterior primary division of the **first cervical nerve** passes to the plexus it runs outwards on the posterior arch of the atlas beneath the vertebral artery, then it turns forwards, between the vertebral artery and the outer side of the upper articular process of the atlas, and finally it descends, in front of the transverse process of the atlas, and unites with the upper branch of the second nerve, forming with it the first loop of the plexus. It gives branches to the rectus capitis lateralis, longus capitis (rectus capitis anterior major), and to the rectus capitis anterior (minor). It communicates with the ganglion of the trunk of the vagus, with the superior cervical ganglion of the sympathetic system, and by two branches with the hypoglossal nerve (fig. 676). These communications with the latter form the descendens hypoglossi and give the branches to the genio-hyoid and thyreo-hyoid muscles.

The **second cervical nerve** (anterior primary division) passes behind the upper articular process of the axis and the vertebral artery, and between the intertransverse muscles extending from the first to the second cervical vertebræ, to the interval between the scalenus medius and the longus capitis (rectus capitis anterior major), where it divides into two parts. The upper part ascends and unites with the first nerve to form the first loop of the plexus, and the lower branch passes downwards and backwards and joins the upper branch of the third nerve in the second loop of the plexus (figs. 675, 676). It gives off the small occipital nerve and a filament to the sterno-mastoid, which communicates with the spinal accessory nerve in the substance of the muscle, and it gives branches which assist in forming the ansa hypoglossi, the cervical cutaneous, and the great auricular nerve (fig. 676).

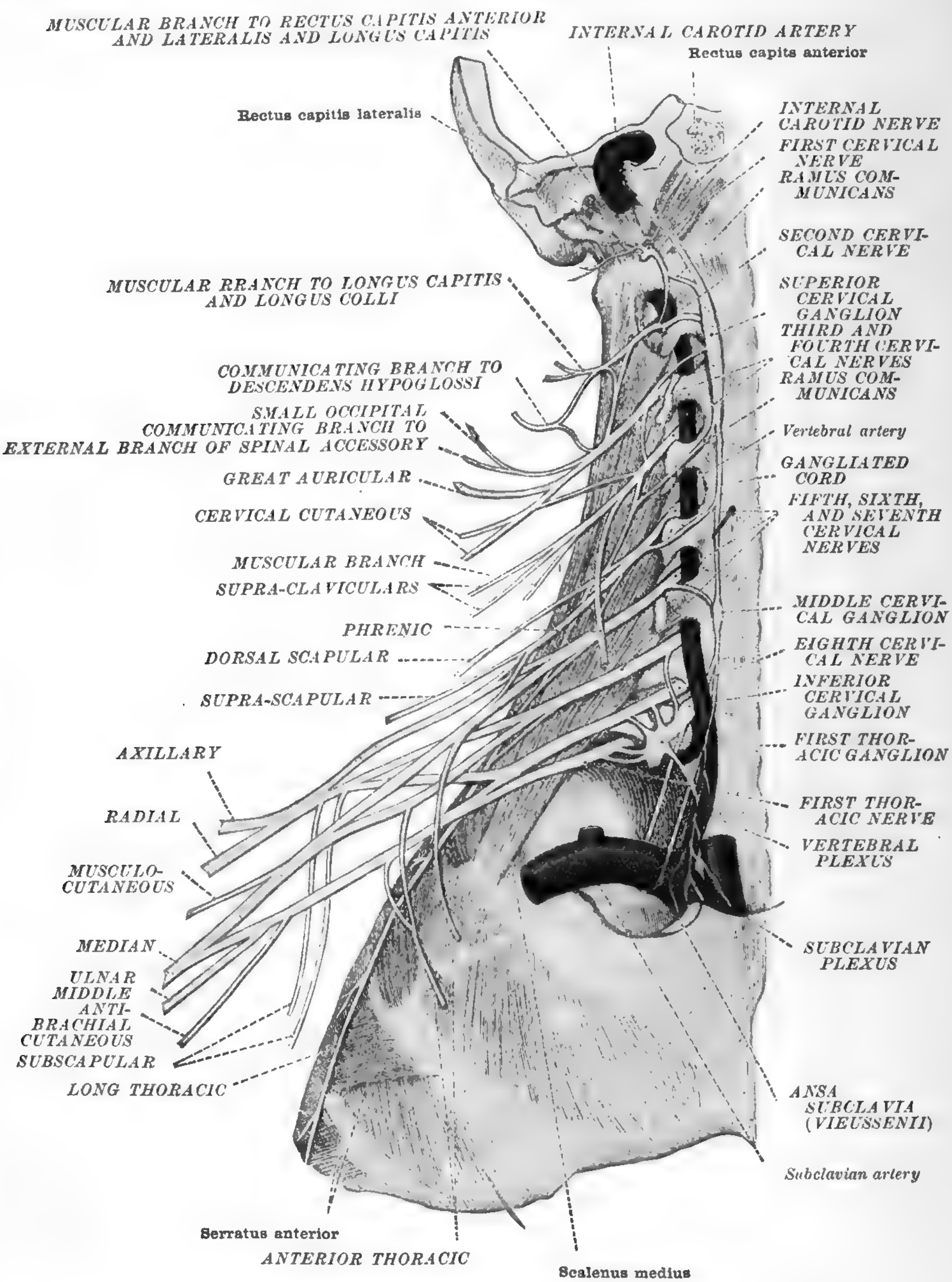
The **third** and **fourth cervical nerves** pass behind the vertebral artery (fig. 675) and between the intertransverse muscles to the interval between the scalenus medius and the longus capitis (rectus capitis anterior major), where the third unites with the second and fourth nerves and completes the lower two loops of the plexus. The anterior divisions of these nerves are about double the size of the preceding. The third gives off a branch to the ansa hypoglossi, the larger part of the great auricular and cervical cutaneous nerves, a branch to the phrenic, a branch to the supra-clavicular nerves, and muscular branches to the scalenus medius, levator scapulæ, longus capitis, and trapezius (fig. 676). This last branch communicates with the spinal accessory nerve beneath the muscle. The fourth nerve gives a branch to the phrenic, a branch to the supra-clavicular nerves, and muscular branches to the scalenus medius, levator scapulæ, longus colli, and trapezius (fig. 676). The branch to the trapezius unites with one from the third nerve and communicates with the spinal accessory nerve beneath the muscle.

Each root of the plexus receives a communicating grey ramus from the superior cervical ganglion of the sympathetic, and from the roots and loops of the plexus a number of branches arise which form two main groups, the superficial and the deep.

SUPERFICIAL BRANCHES OF THE CERVICAL PLEXUS

The superficial branches are described, according to the direction in which they run, as ascending, transverse, and descending branches. The *ascending branches* are the small occipital and the great auricular nerves. There is only one *transverse*

FIG. 675.—ORIGIN OF THE CERVICAL AND BRACHIAL PLEXUS. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)

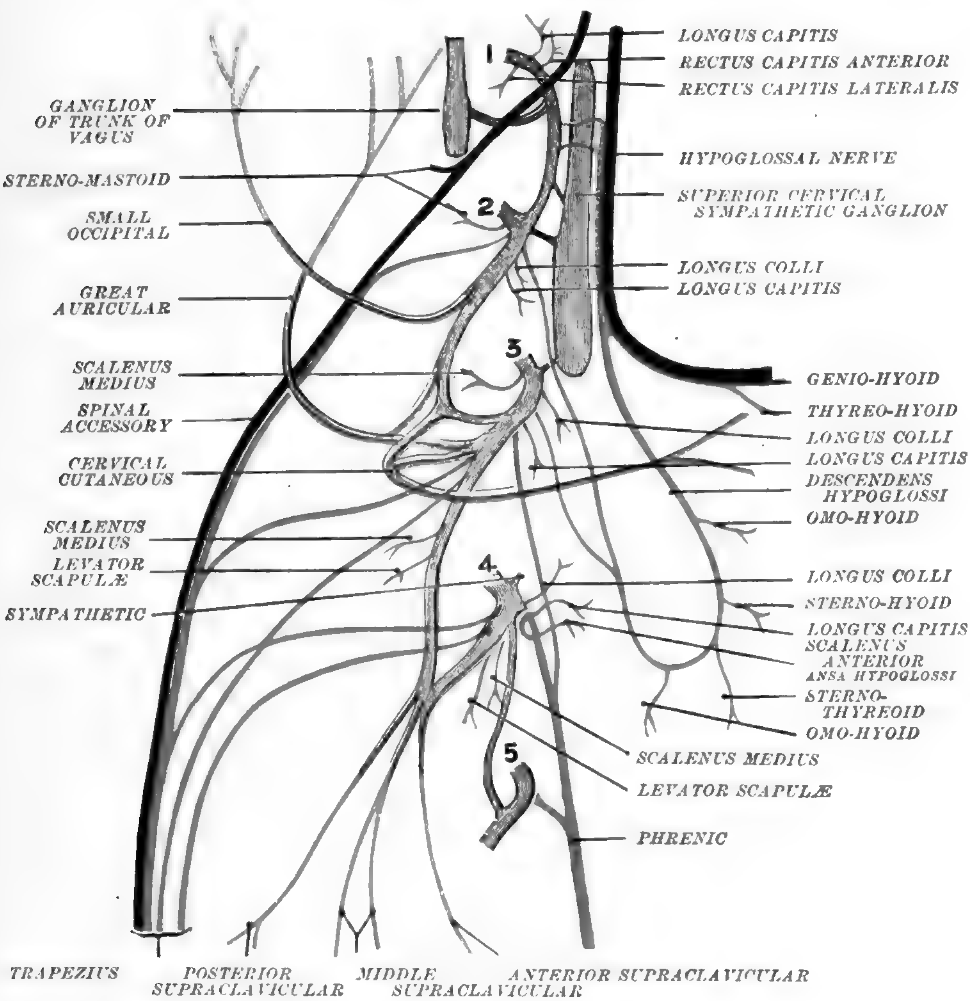


branch, the cervical cutaneous (transverse cervical), and the *descending branches* are distinguished as the supraclavicular nerves.

The ascending branches.—(1) The **Small Occipital Nerve** (fig. 675) arises from

the second and third cervical nerves or from the loop between them and runs upwards and backwards to the posterior border of the sterno-mastoid, where it hooks around the lower border of the spinal accessory nerve and then ascends along the posterior border of the muscle to the mastoid process. It pierces the deep cervical fascia and passes across the posterior part of the insertion of the sterno-mastoid into the superficial fascia of the scalp, in which it breaks up into auricular, mastoid, and occipital terminal branches. (*a*) The **auricular branch** runs upwards and slightly forwards to reach the integument on the upper median part of the pinna, to which it is distributed. (*b*) The **mastoid branch** is distributed to the skin covering the base of the mastoid process. (*c*) The **occipital branches** ramify over the occipitalis

FIG. 676.—DIAGRAM OF THE CERVICAL PLEXUS.



muscle and are distributed to the skin of the scalp; they communicate with one another and with the great occipital nerve. The branches of the small occipital nerve anastomose with twigs of the posterior auricular, great auricular, and great occipital nerves (fig. 677).

(2) The **Great Auricular Nerve** arises from the second and third cervical nerves (figs. 675, 676). It accompanies the small occipital to the posterior border of the sterno-mastoid, but at that point it diverges from the small occipital (fig. 677) and runs upwards and forwards across the sterno-mastoid towards the angle of the mandible. When it is about half-way across the muscle it begins to break up into its terminal branches, which are named, according to the area of their distribution,

mastoid, auricular, and facial. As the nerve ascends obliquely across the sterno-mastoid it is embedded in the deep cervical fascia, is covered by superficial fascia and the platysma, and it lies parallel with and slightly behind the external jugular vein. (*a*) The **mastoid branch** is small, and is distributed to the integument covering the mastoid process. It anastomoses with the posterior auricular and small occipital nerves. (*b*) The **auricular branches** are three or four stout twigs which anastomose with the branches of the posterior auricular nerve; they cross the superficial surface of the posterior auricular branch of the facial, and are distributed to the skin on the back of the pinna with the exception of its uppermost part. One or two twigs pass through fissures in the cartilage of the pinna, and are distributed to

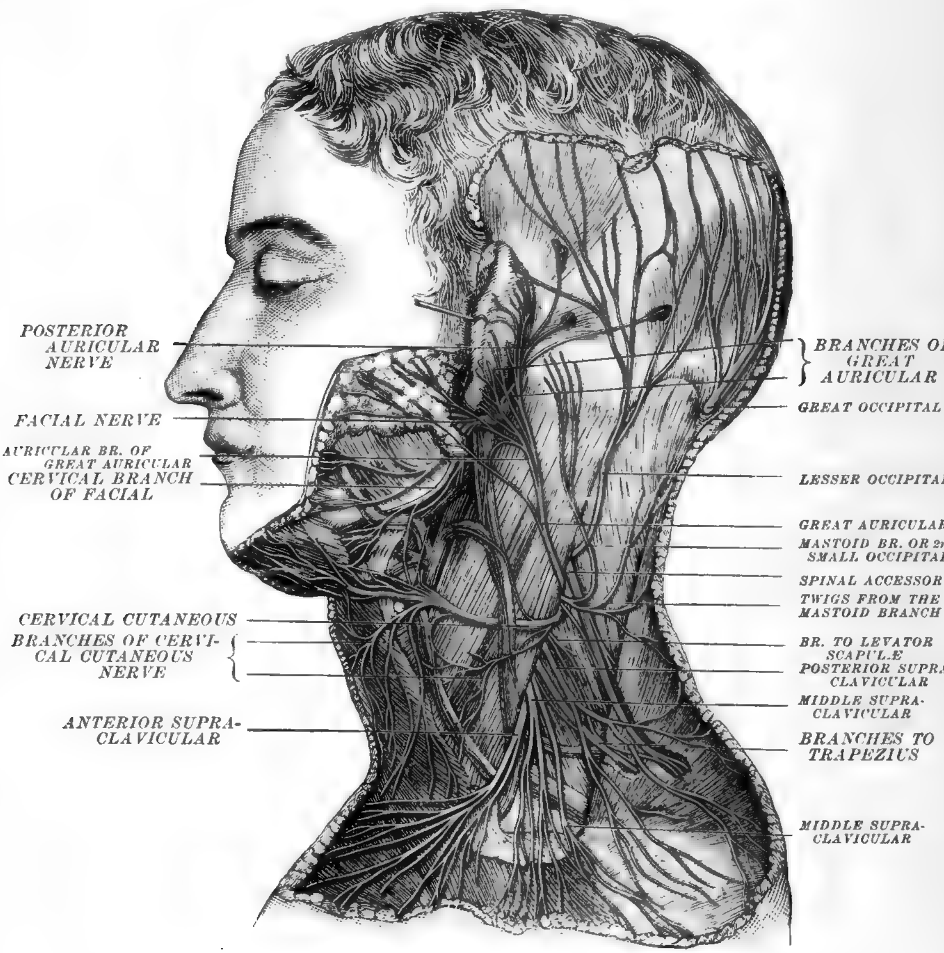


FIG. 677.—SUPERFICIAL BRANCHES OF THE CERVICAL PLEXUS
After Hirschfeld and Leveillé.)

the integument on the outer surface of the lobule and the outer surface of the lower part of the helix and anthelix. (*c*) The **facial** branches pass upwards and forwards among the superficial lobules of the parotid gland, and supply the skin over that gland and immediately in front of it, and they anastomose in the substance of the gland with the cervico-facial division of the facial nerve. In some cases fine twigs may be traced forwards nearly to the angle of the mouth.

Transverse branch.—The **Superficial Cervical Cutaneous Nerve** (transverse cervical) arises from the second and third cervical nerves (figs. 675, 676), and appears at the posterior border of the sterno-mastoid, a little below the great auricular nerve. It passes transversely across the sterno-mastoid under cover of the integument, platysma, and external jugular vein, and divides into a number of twigs which

spread out after the manner of a fan, and, as they approach the middle line, extend from the chin to the sternum (fig. 677). The upper two or three of these twigs unite, beneath the platysma, with the cervical (inframandibular) branch of the facial and thus form loops. From the terminal branches of the nerve numerous twigs arise which pierce the platysma and end in the skin of the front part of the neck.

The descending or supra-clavicular branches.—These are derived from the third and fourth cervical nerves (figs. 675 and 676), and arise under cover of the sterno-mastoid. At their commencements they are usually united with the muscular branches destined for the trapezius. They become superficial at the middle of the posterior border of the sterno-mastoid, and as they pass downwards they pierce the deep cervical fascia. (1) The **anterior supra-clavicular (suprasternal) branches** (fig. 677) are small, and cross over the clavicular origin of the sterno-mastoid to reach the integument over the upper part of the manubrium sterni. They also supply the sterno-clavicular joint. (2) The **middle supra-clavicular (supra-clavicular) nerves** are of considerable size. They cross in front of the middle third of the clavicle under cover of the platysma, and are distributed to the skin covering the upper part of the pectoralis major as low as the third rib. (3) The **posterior supra-clavicular (supra-acromial) branches** (fig. 677) cross the clavicular insertion of the trapezius and the acromion process. They are distributed to the skin which covers the upper two-thirds of the deltoid muscle and they supply the acromio-clavicular joint.

Deep Branches of the Cervical Plexus

The deep branches of the plexus pass outwards and dorsalwards, or ventralwards and inwards; therefore they form two series, the external and the internal.

The **external branches** of the deep series include communicating branches from the second, third, and fourth cervical nerves to the spinal accessory nerve, and muscular branches to the sterno-mastoid and the scalenus medius, levator scapulæ, and trapezius.

The communicating branches of the external.—The communicating branch from the second cervical nerve is ultimately distributed to the sterno-mastoid, and those from the third and fourth nerves end in the trapezius.

1. The **Nerve to the Sterno-mastoid** arises from the second cervical nerve (fig. 677). It pierces the deep surface of the sterno-mastoid, and communicates within the muscle with the spinal accessory nerve.

2. The **Nerves to the Scalenus Medius** (fig. 676) are derived from the third and fourth cervical nerves close to their exit from the intervertebral foramina.

3. The **Nerves to the Levator Scapulæ** (fig. 676) are derived from the third and fourth cervical nerves, and occasionally from the second. They pierce the superficial surface of the levator scapulæ, and supply the upper three divisions of that muscle.

4. The **branches to the Trapezius** (fig. 676) are usually in the form of two stout twigs which are given off by the third and fourth cervical nerves. They emerge from under cover of the sterno-mastoid at its posterior border and cross the posterior superior triangle of the neck at a lower level than the spinal accessory nerve (fig. 677). They pass under cover of the trapezius in company with the last-named nerve, and communicate with it to form the **subtrapezial plexus,** from which the trapezius is supplied.

The **internal branches** of the deep series also comprise communicating and muscular branches.

The **communicating branches of the internal** (figs. 675 and 676) include (1) branches which connect each of the first four cervical nerves with the superior cervical ganglion of the sympathetic; (2) a communicating branch to the vagus; (3) a communicating branch to the hypoglossal; and (4) communicating branches which pass from the second and third cervical nerves to the *descendens hypoglossi* (see p. 988). The ultimate distribution of the twigs connected with the sympathetic and the vagus nerves is not known, but the fibres which pass to the hypoglossal nerve pass from it to the thyreo-hyoideus muscle, and to the descendens hypoglossi, and the latter communicates with the branches from the second and third cervical nerves, forming with them a loop, the **ansa hypoglossi,** which lies on the carotid

sheath. From this loop the two bellies of the omo-hyoid muscle and the sterno-hyoid and sterno-thyreoid muscles are supplied.

The **muscular branches** supply the rectus capitis lateralis, the longus capitis (rectus capitis anterior major), the rectus capitis anterior (minor), the scalenus anterior, and the diaphragm. The nerve to the latter muscle is the **phrenic.**

1. The **branch to the Rectus Capitis Lateralis** is furnished to that muscle by the first nerve as it crosses the deep surface of the muscle.

2. The **nerve to the Rectus Capitis Anterior** (minor) is given off by the first nerve at the upper part of the loop in front of the transverse process of the atlas.

3. The **Longus Capitis** (rectus capitis anterior major) receives twigs from the upper four cervical nerves.

4. The **Longus Colli** receives branches from the second, third, and fourth cervical nerves, and additional branches also from the fifth and sixth nerves.

5. The **Phrenic Nerve** (fig. 676) springs chiefly from the fourth cervical nerve, but it usually receives a twig from the third and another from the fifth cervical nerve, a small communicating branch from the sympathetic, and, rarely, a branch from the vagus. The twig from the fifth cervical nerve is frequently connected with the nerve to the subclavius. After the union of its roots the phrenic nerve passes downwards and inwards on the scalenus anterior (fig. 679). In this part of its course it is crossed by the tendon of the omo-hyoid and by the transverse cervical and transverse scapular (suprascapular) arteries. It is overlapped by the internal jugular vein, and it is covered by the sterno-mastoid muscle. At the root of the neck the left phrenic nerve lies behind the terminal portion of the thoracic duct, and each nerve passes off the anterior border of the scalenus anterior and descends in front of the first part of the subclavian artery and the pleura immediately below that artery; it passes behind the terminal part of the subclavian vein, crosses either in front of or behind the internal mammary artery and gains the inner surface of the pleural sac. From the root of the neck the relations of the phrenic nerves differ. The **right phrenic nerve** descends along the inner surface of the right pleural sac and crosses in front of the root of the lung. It is accompanied by the pericardiaco-phrenic artery (comes nervi phrenici), and it is in relation internally, and from above downwards, with the right innominate vein, the superior vena cava, and the pericardium, the latter membrane separating it from the wall of the right atrium (auricle). The **left phrenic nerve** descends along the inner surface of the left pleural sac accompanied by the pericardiaco-phrenic (comes nervi phrenici) artery. In the superior mediastinum it lies between the left common carotid and the left subclavian arteries, and it crosses in front of the left vagus, the left superior intercostal vein, and the arch of the aorta. Below the arch of the aorta it crosses in front of the root of the left lung, and then lies along the left lateral surface of the pericardium, which separates it from the wall of the left ventricle.

Branches.—Both phrenic nerves distribute branches to the pericardium and to the pleura. The right nerve gives off a branch, **pericardiac,** which accompanies the superior vena cava and supplies the pericardium. Each phrenic nerve divides into numerous terminal **phrenico-abdominal** branches. As a rule, the right phrenic nerve divides into two main terminal branches, an anterior and a posterior. The *anterior* branch runs forwards and one of its terminal filaments anastomoses with the phrenic of the opposite side in front of the pericardium; others descend between the sternal and costal origins of the diaphragm into the abdomen, where some of them supply the diaphragm and others descend in the falciform ligament to the peritoneum of the upper surface of the liver. The *posterior* branch passes through the vena caval opening and ramifies upon the lower surface of the diaphragm, anastomosing with the diaphragmatic plexus of the sympathetic, and its terminal branches supply the muscular fibres of the right half of the diaphragm, the inferior vena cava, and the right suprarenal gland.

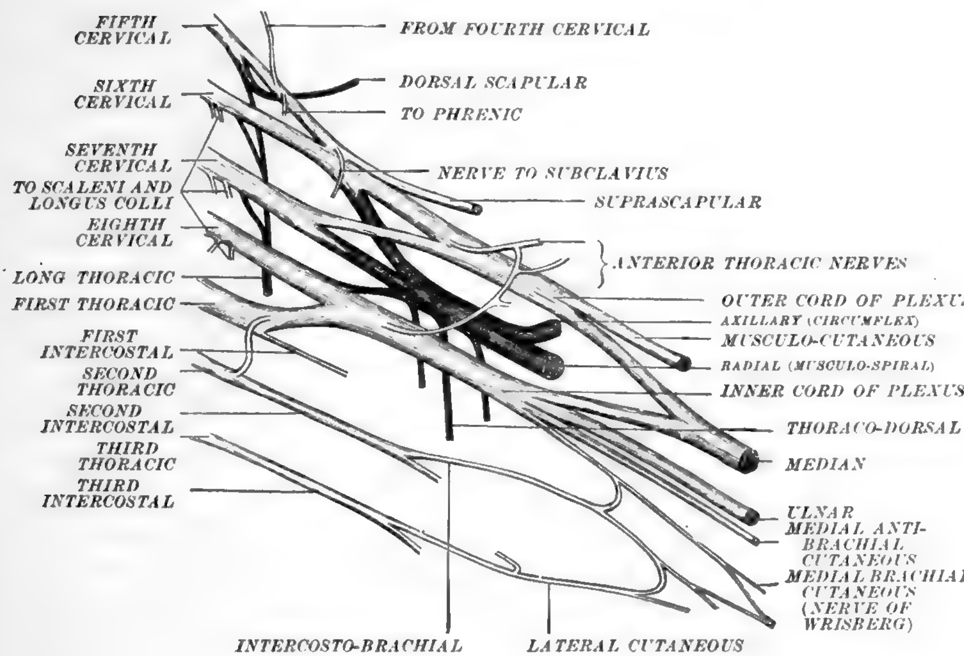
The left phrenic nerve divides into several branches. One of the most anterior branches anastomoses with the right phrenic nerve; the others pierce the diaphragm and ramify on its under surface, where they anastomose with filaments of the left diaphragmatic plexus of the sympathetic and supply the left half of the diaphragm and the left suprarenal gland. The left phrenic nerve is considerably longer than the right nerve, partly on account of the lower level of the diaphragm on the left side, and partly on account of the greater convexity of the left side of the pericardium.

THE BRACHIAL PLEXUS

The **brachial plexus** (figs. 675, 678, 679) is formed by the anterior primary divisions of the **four lower cervical nerves** and the greater part of the **first thoracic nerve.** It is usually joined by small communicating twigs from the **fourth cervical** and **second thoracic nerves.**

The anterior primary divisions of the lower four cervical nerves, after crossing behind the vertebral artery and between the anterior and posterior parts of the intertransverse muscles, pass into the posterior triangle in the interval between the adjacent borders of the anterior and middle scalene muscles, where the fifth and sixth nerves receive a grey ramus communicans each from the middle cervical sympathetic ganglion, and the seventh and eighth nerves each receive a grey ramus from the inferior cervical sympathetic ganglion. The first thoracic is connected by two rami communicantes with the first thoracic sympathetic ganglion, and it divides into a smaller and a larger branch. The smaller branch passes along the intercostal space as the intercostal nerve, and the larger branch, after being joined by a communication from the second

Fig. 678.—Diagram of a Common Form of Brachial Plexus.
The posterior cord of the plexus is darkly shaded.



thoracic nerve, passes upwards and outwards, in front of the neck of the first rib and behind the apex of the pleural sac, into the lower part of the posterior triangle of the neck, where it takes part in the formation of the plexus.

The anterior primary divisions of those cervical nerves that form the brachial plexus may be considered as typically giving off anterior and posterior branches, except that the fifth and sixth nerves often unite before branching and give off their posterior branches as a common trunk, and the eighth nerve often receives its communication from the first thoracic nerve before giving off its posterior branch.

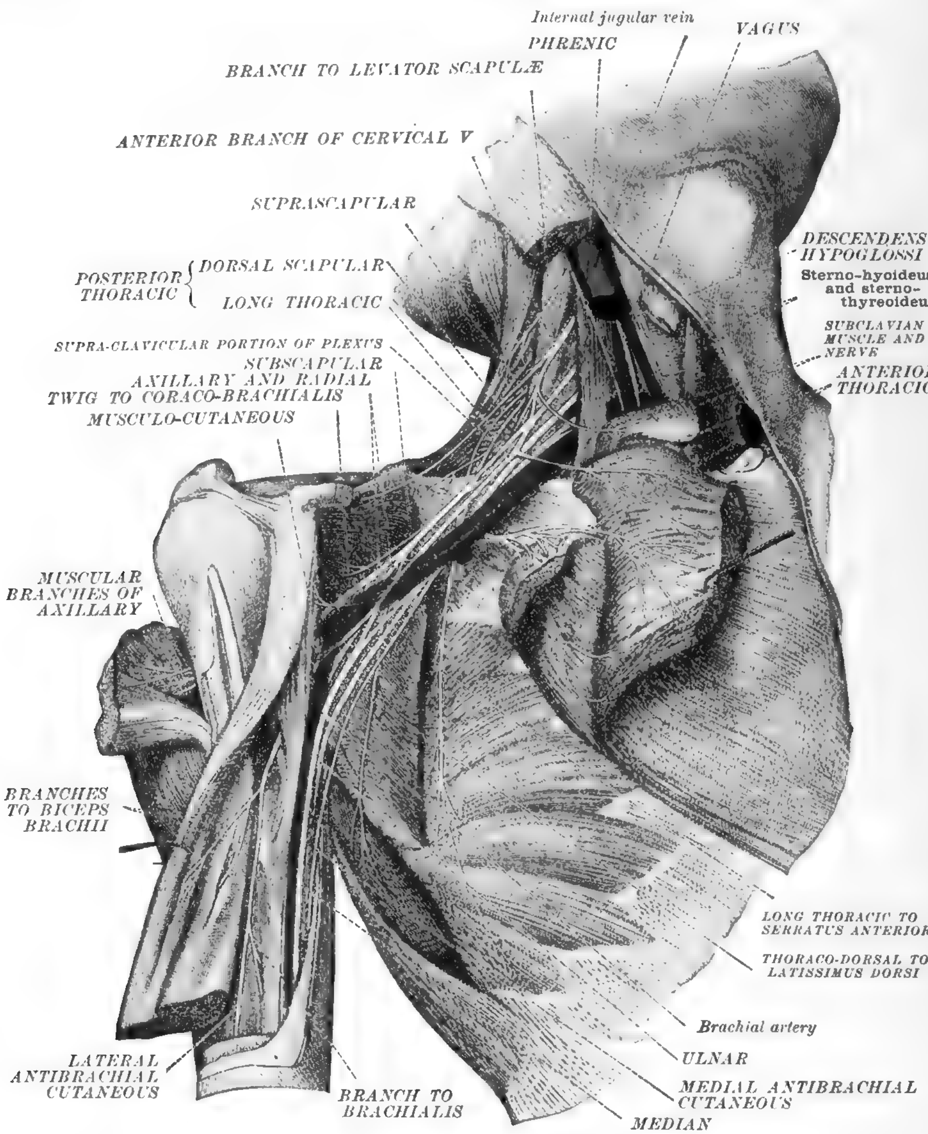
It is on account of this variation in the point of union of the fifth and sixth cervical nerves and of the eighth cervical and first thoracic nerves that so many different forms of the plexus have been pictured and described. But if the differences in primary branching be borne in mind, the formation of the plexus is always uniform and simple, notwithstanding its different appearances.

The three cords are formed from these branches in the following manner:—(1) The outer cord is formed by the anterior branches of the fifth, sixth, and seventh nerves; (2) the inner cord, by the anterior branches of the eighth cervical and first

thoracic nerves; and (3) the posterior cord, by the posterior branches of all of these cervical nerves.

The plexus extends from the outer border of the scalenus anterior, where the roots of its constituent nerves appear, to the lower border of the pectoralis minor, where each of its three cords divides into two terminal branches, and it lies in the posterior triangle, in the root of the neck, and in the axillary fossa. In the posterior triangle and the root of the neck it is in relation behind with the scalenus medius (figs. 675,

FIG. 679.—THE BRACHIAL PLEXUS AND BRANCHES OF THE REGION OF THE NECK AND SHOULDER. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



679). In the posterior triangle it is covered superficially by the skin and superficial fascia, the platysma, the supra-clavicular branches of the cervical plexus, and the deep fascia, and it is crossed by the lower part of the external jugular vein, by the nerve to the subclavius, the transverse cervical vein and the transverse scapular (suprascapular) vein, the posterior belly of the omo-hyoid muscle, and by the transverse cervical artery. At the root of the neck it lies behind the clavicle and the subclavius muscle, and the transverse scapular (suprascapular) artery crosses in front

of it. In the axillary fossa the cords are arranged around the axillary artery, the outer cord lying to the outer side, the inner cord to the inner side, and the posterior cord behind the artery. In this region the posterior relations of the plexus are the fat in the upper part of the fossa and the subscapularis muscle, and it is covered in front by the pectoral muscles and the coraco-clavicular fascia. The lower border of the plexus is in relation in the posterior triangle and the root of the neck with the pleura and the first rib, and it is overlapped in front by the third part of the subclavian artery. In the axillary fossa the lower cord which forms the lower border of the plexus is overlapped anteriorly by the axillary vein. The upper and outer border of the plexus has no very important relations.

The **branches** of the plexus are given off either from the roots above the clavicle, or from the cords behind and below the clavicle. The branches from the cords are lateral branches and terminal branches.

The branches from the supra-clavicular portion.—After the roots of the plexus have received communications from the sympathetic, which have already been referred to, they give off a series of muscular branches, viz.—the posterior thoracic nerves (the dorsal scapular and the long thoracic nerves), the suprascapular nerve, a communicating twig to the phrenic, the nerve to the subclavius, and small twigs to the scalene muscles and the longus colli muscle.

The **posterior thoracic nerves** are two in number:—(*a*) the **dorsal scapular** (nerve to the rhomboids) arises principally from the fifth cervical nerve, but it frequently receives a twig from the fourth nerve (fig. 675). It passes downwards and dorsalwards, across the middle scalene, parallel with and below the spinal accessory nerve to the anterior border of the levator scapulæ, under which it disappears. It continues its descent under cover of the levator scapulæ and the rhomboids almost to the lower angle of the scapula, lying a little internal to the posterior border of the bone, and it supplies the lower fibres of the levator and the smaller and larger rhomboid muscles.

(*b*) The **Long Thoracic Nerve** (external respiratory of Bell) usually arises, by three roots, from the fifth, sixth, and seventh cervical nerves. The last is sometimes absent (figs. 675 and 678). The upper two roots traverse the substance of the scalenus medius; the root from the seventh passes in front of that muscle. Twigs are furnished to the superior portion of the serratus anterior by the upper two roots; lower down they unite and are subsequently joined by the root from the seventh when present. The trunk of the nerve passes downwards behind the brachial plexus and the first stage of the axillary artery, and runs along the axillary surface of the serratus anterior (magnus), supplying twigs to each of the digitations of that muscle (fig. 679).

The **Suprascapular Nerve** (fig. 675) receives fibres from the fifth and sixth cervical nerves, and occasionally also a twig from the fourth nerve. It is a nerve of considerable size, and it passes downwards and dorsalwards parallel with the dorsal scapular nerve, at first along the upper border of the posterior belly of the omo-hyoid muscle, then internal to the latter muscle and under cover of the anterior border of the trapezius to the suprascapular notch (fig. 679), where it comes into relation with the transverse scapular (suprascapular) artery. It is separated from the artery at the notch by the superior transverse ligament, the nerve passing through the notch and the artery above the ligament. After entering the supraspinous fossa the nerve supplies branches to the supraspinatus and a branch to the shoulder-joint; then it descends through the great scapular notch between the bone and the inferior transverse ligament to the infraspinous fossa, where it terminates in the infraspinatus muscle.

The **communicating twig to the phrenic** (fig. 675) arises from the fifth nerve close to the point where the latter nerve receives its communicating twig from the cervical plexus.

The **nerve to the subclavius** (fig. 679) is a small twig which arises from the fifth nerve or from the upper trunk of the plexus, but occasionally it receives additional fibres from the fourth and sixth nerves. It runs downwards in front of the lower part of the plexus and the third stage of the subclavian artery and, after giving off sometimes a communicating branch to the phrenic, pierces the posterior layer of the coraco-clavicular fascia, and enters the subclavius at its lower border.

Variety.—In rare cases the entire phrenic nerve may pass *viâ* the nerve to the subclavius in front of the third stage of the subclavian artery.

The *scaleni* and *longus colli* (figs. 675, 678) are supplied by twigs which arise from the lower three or four cervical nerves immediately after their exit from the intervertebral foramina.

The lateral branches of the infra-clavicular portion are the anterior thoracic nerves (external and internal), from the outer and inner cords respectively, the medial antibrachial (internal) cutaneous and the medial brachial (lesser internal) cutaneous nerves, from the inner cord, and the subscapular nerves and thoraco-dorsal from the posterior cord.

The **external anterior thoracic nerve** arises from the outer cord of the plexus and contains fibres from the fifth, sixth, and seventh nerves (figs. 675, 678, 679). After communicating with the internal anterior thoracic it pierces the coraco-clavicular fascia and ends in branches that supply the pectoralis major muscle. The **internal anterior thoracic nerve** arises from the inner cord (figs. 675, 678, 679), contains fibres from the eighth cervical and first thoracic nerves, and passes forwards between the first stage of the axillary artery and the axillary vein. It unites with a branch from the external anterior thoracic, to form a loop which is placed in front of the first stage of the axillary artery; it gives branches to the pectoralis minor, and branches which pass through the latter muscle and end in the pectoralis major. From the loop additional branches are furnished to the pectoralis major.

The **Medial Brachial** (**Lesser Internal**) **Cutaneous Nerve,** or **nerve of Wrisberg** (fig. 678), arises from the inner cord of the brachial plexus and sometimes contains fibres from the eighth cervical and first thoracic nerves, but usually fibres from the first thoracic nerve alone. It runs downwards on the inner side of the axillary vein, being separated by that vessel from the ulnar nerve, and it continues downwards with a slight inclination dorsalwards under cover of the deep fascia on the inner side of the arm. At the middle of the arm it pierces the deep fascia, and near the bend of the elbow it turns somewhat sharply dorsalwards to supply the integument which covers the olecranon process (fig. 680). As it traverses the axilla the nerve of Wrisberg communicates with the intercosto-brachial nerve, forming one, or sometimes two loops (fig. 678). In its course down the arm it gives a few fine twigs to the integument. This nerve may be absent, its place being taken by the intercosto-brachial or by part of the posterior brachial (internal) cutaneous branch of the radial (musculo-spiral) or, rarely, by a branch from the first intercostal nerve.

The **Medial Antibrachial** (**Internal**) **Cutaneous Nerve** (figs. 675 and 678) arises from the inner cord immediately above the ulnar nerve. It contains fibres from the eighth cervical and first thoracic nerves. At its origin it lies directly on the inner side of the axillary artery (fig. 679), but it soon becomes more superficial and then lies in the groove between the artery and the vein. In the upper two-thirds of the arm it lies in front and to the inner side of the brachial artery.

At the junction of the middle and lower thirds of the arm this nerve pierces the deep fascia, in company with the basilic vein, and divides into an anterior and a posterior branch. Previous to its division it gives off twigs which pierce the deep fascia and supply the integument of the upper and inner part of the arm. The **volar (anterior) branch** is larger than the ulnar (posterior); it passes in front of or behind the median basilic vein, and divides into several twigs which run down the forearm, supplying the integument covering its anterior and internal aspect as far as the wrist, and anastomosing with the branches of the ulnar nerve. The **ulnar (posterior) branch** passes downwards and dorsalwards in front of the internal condyle of the humerus, and divides into branches which supply the skin on the postero-internal aspect of the forearm. It anastomoses with the dorsal antibrachial (inferior external) cutaneous branch of the radial (musculo-spiral) nerve and the dorsal branch of the ulnar nerve.

The **Subscapular Nerves** are branches of the posterior cord (fig. 678). They are three in number, are distinguished as upper, thoraco-dorsal or middle, and lower, and are distributed to the subscapularis, latissimus dorsi, and teres major muscles.

The **upper** or **short subscapular nerve** is derived from the fifth and sixth cervical nerves. It lies in the upper and posterior part of the axillary fossa, and it is distributed exclusively to the subscapularis muscle. It is occasionally double.

The **thoraco-dorsal, middle,** or **long subscapular nerve** consists mainly of fibres from the seventh and eighth cervical nerves, but it may contain fibres from the fifth or the sixth nerve. It passes behind the axillary artery, accompanies the

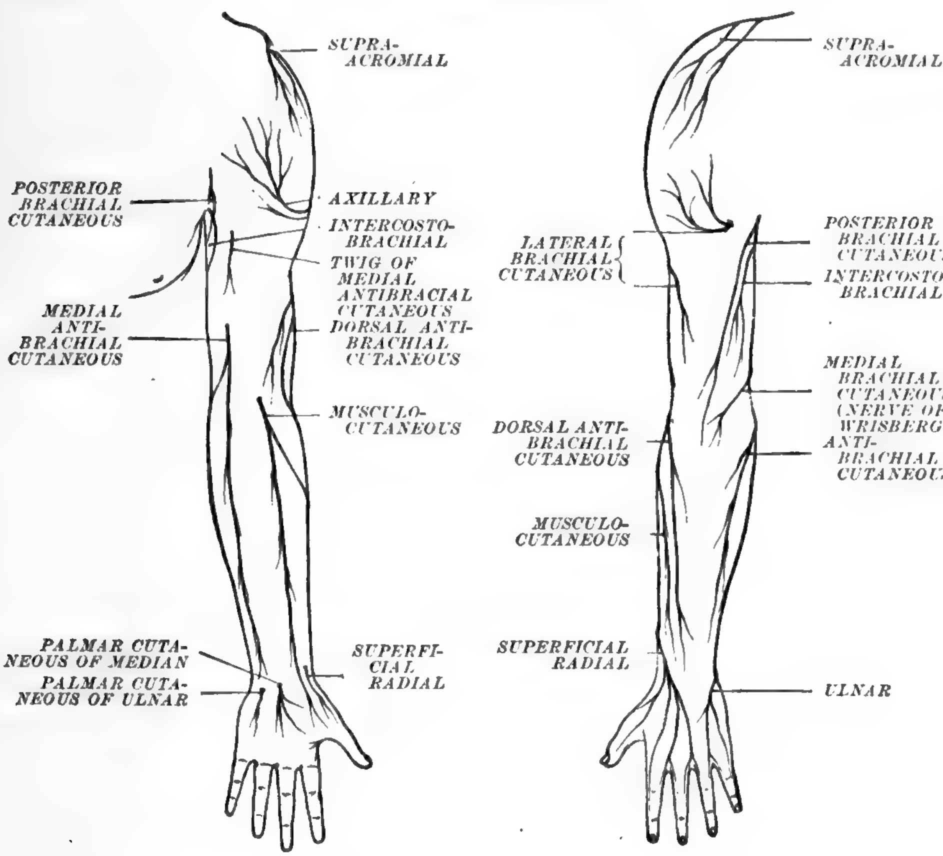
subscapular artery along the axillary margin of the subscapularis muscle, and ends in the latissimus dorsi (fig. 679).

The **lower subscapular nerve,** carrying fibres from the fifth and sixth cervical nerves, passes behind the subscapular artery, below the circumflex branch (dorsalis scapulæ), and is distributed to the teres major, and furnishes to the subscapularis one or two twigs which enter that muscle near its axillary margin.

The **terminal branches** are two from each cord. The posterior cord divides into the axillary (circumflex) and the radial (musculo-spiral) nerves. The outer cord divides into the musculo-cutaneous nerve, and the outer root of the median nerve; the inner cord into the ulnar nerve, and the inner root of the median nerve.

The **Axillary (Circumflex) Nerve** is the smaller of the two terminal branches of the posterior cord, and contains fibres from the fifth and sixth cervical nerves (figs. 675

FIG. 680.—DISTRIBUTION OF CUTANEOUS NERVES ON THE ANTERIOR AND POSTERIOR ASPECTS OF THE SUPERIOR EXTREMITY.



and 678). At the lower border of the subscapularis it passes dorsalwards and accompanies the posterior circumflex artery through the quadrilateral space, which is bounded by the teres major, long head of triceps, and subscapularis muscles, and the surgical neck of the humerus, and it divides into a smaller superior and a larger inferior division. Previous to its division it furnishes an articular twig to the shoulder-joint. This twig pierces the inferior part of the articular capsule.

The **superior division** accompanies the posterior circumflex artery around the neck of the humerus, and gives off a number of stout twigs which enter the deltoid muscle (fig. 679). A few fine filaments pierce the deltoid and end in the integument which covers the middle third of that muscle.

The **inferior division** divides into cutaneous and muscular branches. The cutaneous branch (the **lateral brachial cutaneous nerve**) turns around the posterior border of the deltoid, pierces the deep fascia, and supplies the skin covering the lower

third of the deltoid and a small area of integument below the insertion of the muscle (fig. 680). One muscular branch is distributed to the teres minor; it swells out into an ovoid or fusiform, reddish, gangliform enlargement before entering the muscle. Other branches supply the lower and posterior part of the deltoid.

The **Radial (Musculo-spiral) Nerve** is the largest branch of the brachial plexus. It contains fibres from the sixth, seventh, and eighth cervical and sometimes from the fifth cervical and first thoracic nerves (figs. 675 and 678). It commences at the lower border of the pectoralis minor, as the direct continuation of the posterior cord of the plexus, and passes downwards and outwards in the axillary fossa behind the third part of the axillary artery (fig. 679) and in front of the subscapularis, latissimus dorsi, and teres major muscles. From the lower border of the axillary fossa it descends into the arm, where it lies, at first, on the inner side of the upper third of the humerus, behind the brachial artery and in front of the long head of the triceps; then it runs obliquely downwards and outwards behind the middle third of the humerus, in the groove for the radial nerve (musculo-spiral groove), and between the outer and inner heads of the triceps. It is accompanied, in this part of its course, by the profunda artery. At the junction of the middle and lower thirds of the humerus it reaches the outer side of the arm, pierces the external intermuscular septum, and runs downwards and forwards between the brachio-radialis and extensor carpi radialis longus externally, and the brachialis internally (fig. 682), and it terminates, a short distance above the capitulum, by dividing into deep and superficial terminal branches. In the last part of its course it is accompanied by the anterior terminal branch of the profunda artery.

Branches.—The branches of the radial or musculo-spiral nerve are cutaneous, muscular, articular, and terminal, but for practical purposes it is best to consider them in association with the situations of their origins. While it is **in the axillary fossa** the radial (musculo-spiral) nerve gives branches to the inner and long heads of the triceps (fig. 682), and an internal cutaneous branch. The branch to the long head of the triceps at once enters the substance of the muscle, that to the inner head breaks into branches which terminate in the muscle at different levels, and one of them, the *ulnar collateral nerve*, accompanies the ulnar nerve to the lower part of the arm. The **posterior brachial (internal) cutaneous branch** crosses the tendon of the latissimus dorsi, passes behind the intercosto-brachial (intercosto-humeral) nerve, pierces the deep fascia, and is distributed to the skin of the middle of the back of the arm below the deltoid.

While it lies **behind the middle third of the humerus,** the radial (musculo-spiral) nerve gives branches to the outer and inner heads of the triceps and to the anconeus. The latter branch descends in the substance of the inner head of the triceps, close to the bone, and it is accompanied by a small branch of the profunda artery. The **dorsal antibrachial (external) cutaneous branch,** passing down between the outer and inner heads of the triceps, divides near the elbow into its upper and lower branches (fig. 680), each of which perforates either the outer head of the triceps muscle near its attachment to the humerus or the external intermuscular septum. The **upper branch,** much the smaller, pierces the deep fascia in the line of the external intermuscular septum; it accompanies the lower part of the cephalic vein, and supplies the skin over the lower half of the outer and anterior aspect of the arm. The **lower branch** is of considerable size. It pierces the deep fascia a little below the upper branch, runs behind the external condyle, and supplies the skin of the middle of the back of the forearm as far as the wrist, anastomosing with the medial antibrachial (internal) cutaneous and musculo-cutaneous nerves (fig. 683).

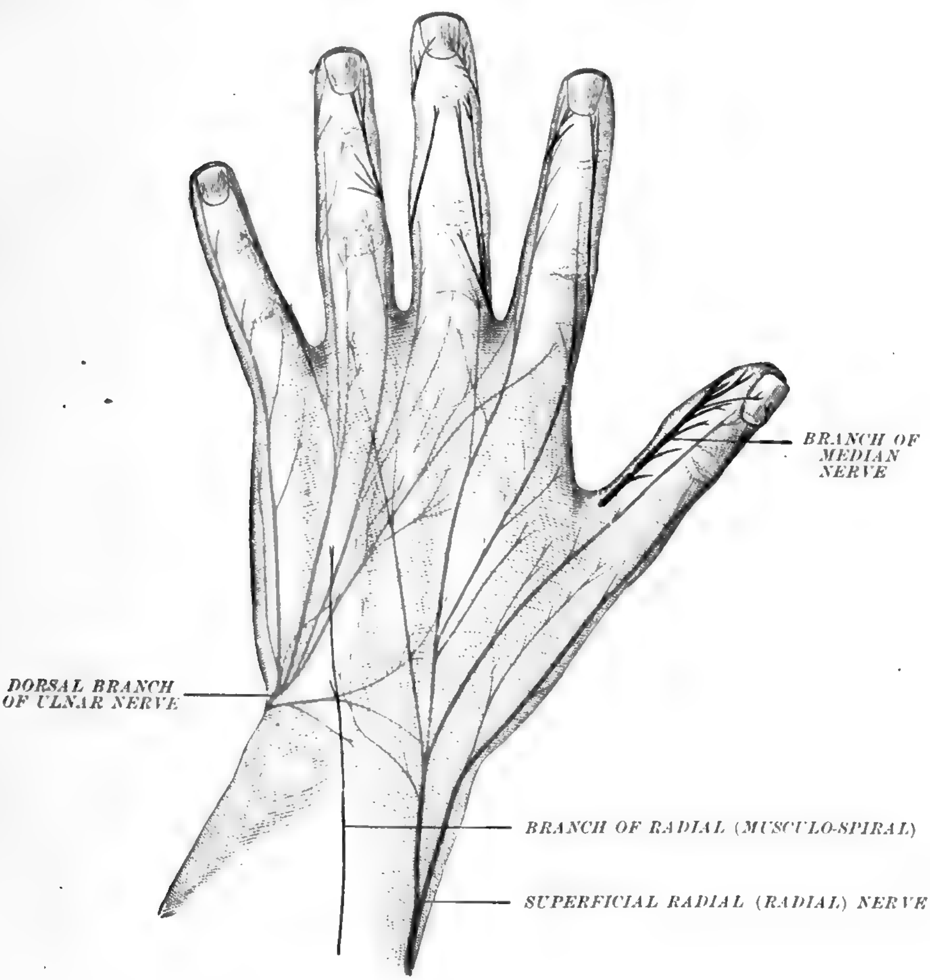
After the radial (musculo-spiral) nerve has pierced the external intermuscular septum it gives branches to the brachio-radialis, extensor carpi radialis longus, and to the outer portion of the brachialis (fig. 683). From one of these branches an articular filament is distributed to the elbow-joint.

The terminal branches are:—a motor branch, the deep radial (posterior interosseous), and a sensory branch, the superficial radial (radial).

The **deep radial (posterior interosseous) nerve** runs downwards in the interval between the brachialis and extensor carpi radialis longus. It passes in front of the outer part of the elbow-joint, and after giving off branches to supply the extensor carpi radialis brevis and supinator, it is crossed in front by the radial recurrent artery (fig. 683). It then runs downwards and backwards through the substance of the supinator, and enters the interval between the superficial and deep layers of

muscles at the back of the forearm, where it comes into relation with the posterior interosseous artery, and accompanies it across the abductor pollicis longus. At the lower border of the latter muscle it gives off a branch to the extensor pollicis longus, and another which crosses this muscle to the extensor indicis proprius. Continuing distalwards as the dorsal antibrachial interosseous nerve it leaves the posterior interosseous artery, dips beneath the extensor pollicis longus, and comes into relation with the anterior interosseous artery. It accompanies this artery upon the interosseous membrane and the back of the radius, passes through the groove for the extensor digitorum communis and extensor indicis proprius to the back of the wrist, and terminates

Fig. 681.—A Dissection of the Cutaneous Nerves on the Dorsal Aspect of the Hand and Fingers. (H. St. J. B.)
The branches of the median nerve are shown in black



in a gangliform enlargement which gives branches to the carpal articulations. The muscles supplied by the deep radial (posterior interosseous) nerve are the extensor carpi radialis brevis, brachio-radialis (supinator longus), extensor digitorum communis, extensor digiti quinti proprius, extensor carpi ulnaris, extensor indicis proprius, and the extensor muscles of the thumb. The supinator (brevis) receives two twigs, one of which is given off before the nerve pierces the muscle and the other while it is passing through it.

The **superficial radial (radial) nerve** is somewhat smaller than the deep radial (posterior interosseous), and is a purely cutaneous nerve. It runs downwards under cover of the brachio-radialis, passing in front of the elbow-joint, the radial recurrent

artery, and the supinator (brevis). At the lower border of the supinator it approaches the radial artery at an acute angle, and runs parallel to the outer side of that vessel in the middle third of the forearm, across the pronator teres. At the lower border of the pronator teres it bends backwards on the deep surface of the tendon of the brachio-radialis, and appears on the back of the forearm. It pierces the deep fascia and is directed across the dorsal carpal (posterior annular) ligament towards the back of the wrist, where it divides into its terminal branches (fig. 683). The most lateral of these supplies the skin on the radial part of the thenar eminence; the most medial, designated the **ulnar anastomotic branch,** communicates with the dorsal branch of the ulnar nerve. The other terminal branches, the **dorsal digital nerves,** supply to a variable extent the skin on the dorsum of the first digit, both sides of the second and third digits, and part of the radial side of the fourth digit. These branches usually extend to the base of the nail of the first digit, to the distal interphalangeal joint of the second, not quite to the proximal interphalangeal joint of the third, and sometimes to the metacarpo-phalangeal joint of the fourth digit.

The **terminal branches of the outer cord** of the brachial plexus are the musculo-cutaneous and the outer component of the median. The latter nerve will be described with the inner cord.

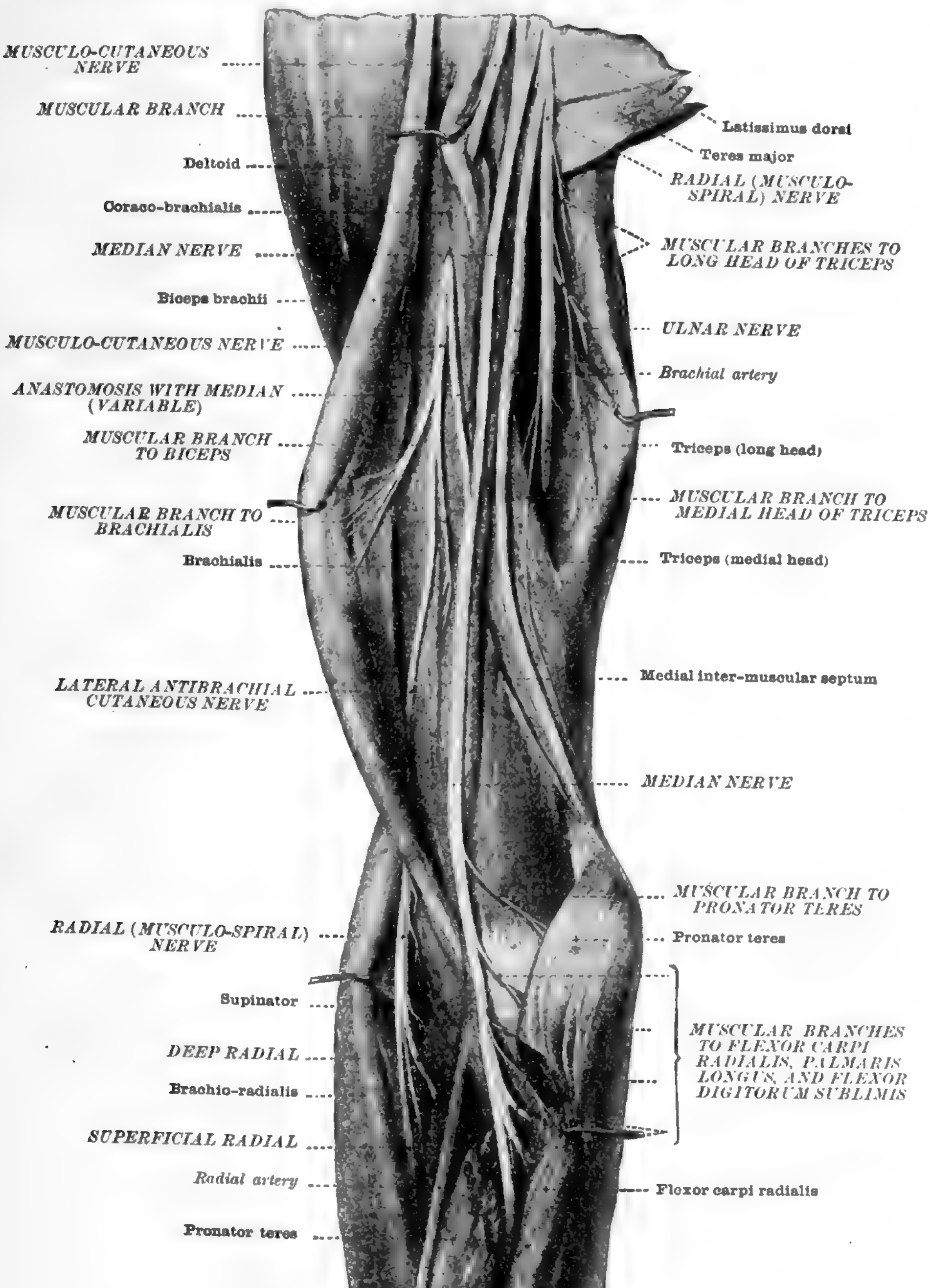
The **musculo-cutaneous nerve** is composed of fibres derived chiefly from the anterior divisions of the fifth and sixth cervical nerves, together usually with some fibres from that of the seventh (figs. 675 and 678). The nerve to the coraco-brachialis usually consists of two or three twigs given off from the nerve close to its origin before it enters the muscle (fig. 679). Sometimes, however, the fibres from the seventh nerve pass directly to this muscle without joining the main trunk. The musuclo-cutaneous nerve is placed at first close to the outer side of the axillary artery (fig. 679), but soon it leaves that vessel and, piercing the coraco-brachialis muscle, it passes obliquely downwards and outwards between the biceps and brachialis muscles. Soon after piercing the coraco-brachialis it gives off muscular branches to each head of the biceps and to the brachialis (fig. 682). It also gives twigs to the humerus, to the nutrient artery, and gives the chief supply to the elbow-joint. Below the branch to the brachialis is the cutaneous portion of the nerve termed the **lateral antibrachial cutaneous nerve** (fig. 682). This nerve continues downwards between the biceps and brachialis, pierces the deep fascia at the outer border of the former muscle a little above the bend of the elbow, receives a communication from the upper branch of the dorsal antibrachial (upper external) cutaneous branch of the radial (musculo-spiral) nerve, passes behind the median cephalic vein, and divides into an anterior and a posterior branch. The **anterior branch** runs downwards on the outer and anterior part of the forearm, supplying the integument of that region, and it terminates in the skin covering the middle part of the thenar eminence (fig. 683). A short distance above the wrist, after it has received a communicating twig from the superficial radial nerve, it gives off an articular branch to the carpal joints. This branch pierces the deep fascia and accompanies the radial artery to the back of the wrist. The **posterior terminal branch** is small, and is directed downwards and backwards in front of the external condyle of the humerus, to be distributed to the skin on the outer and posterior aspect of the forearm as low as the wrist (fig. 680). It anastomoses with the superficial radial and with the lower branch of the dorsal antibrachial (lower external) cutaneous branch of the radial (musculo-spiral) nerve.

The **terminal branches of the inner cord** of the brachial plexus are the ulnar and the inner component of the median nerve. Neither of these supplies any branches in the upper arm, and thus they differ from the other terminal branches of the plexus. They both supply the muscles and joints of the forearm, and the muscles, joints, and integument of the hand.

The **Ulnar Nerve,** which is the largest branch of the inner cord of the brachial plexus, contains fibres from the anterior divisions of the eighth cervical and first thoracic nerves (figs. 676 and 685). It commences at the lower border of the pectoralis minor and runs downwards in the axillary fossa in the posterior angle between the axillary artery and vein. In the upper half of the arm it lies on the inner side of the brachial artery (fig. 679), but at the level of the insertion of the coraco-brachialis it passes backwards at an acute angle, and, accompanied by the superior ulnar collateral (inferior profunda) artery, it pierces the internal intermuscular septum. After

passing through the septum it runs downwards, in a groove in the inner head of the triceps (fig. 682), to the interval between the olecranon process and the internal condyle of the humerus, and in this part of its course it is closely bound to the

FIG. 682.—NERVES OF THE RIGHT UPPER ARM VIEWED FROM IN FRONT. (Spalteholz.)



muscle by the deep fascia. Immediately below the internal condyle it passes between the two heads of the flexor carpi ulnaris, along the inner side of the internal lateral ligament of the elbow, and it comes into relation with the posterior ulnar recurrent artery.

In the upper part of the forearm it lies on the flexor digitorum profundus, covered by the flexor carpi ulnaris. Near the junction of the upper and middle thirds of the forearm it is joined by the ulnar artery, which accompanies it to its termination, lying throughout on its radial side (fig. 683). In the lower part of the forearm it still rests on the flexor digitorum profundus, but between the flexor carpi ulnaris and flexor digitorum sublimis, and is covered only by skin and fascia. At a variable point in this part of the forearm, usually about 5 to 8 cm. (2 to 3 in.) from the carpus, the nerve divides into its two terminal branches, a dorsal branch to the dorsal aspect of the hand, and a volar branch to the volar aspect.

Branches.—The ulnar resembles the median nerve in not furnishing any branches to the upper arm. As it passes between the olecranon process and the internal condyle it gives off two or three fine filaments to the elbow-joint. In the upper part of the forearm it supplies the flexor carpi ulnaris and the inner portion of the flexor digitorum profundus, and in the lower half it gives off the three cutaneous branches. In the palm of the hand it supplies the integument of the hypothenar eminence, the fifth digit, and half of the fourth digit, and part of the skin of the dorsum. It also supplies the short intrinsic muscles of the hand with the exception of the abductor pollicis, the opponens, the outer head of the flexor pollicis brevis, and the two outer lumbricales.

The **nerves to the flexor carpi ulnaris** and to the inner two divisions of the **flexor digitorum profundus** arise from the ulnar nerve in the upper third of the forearm.

Cutaneous Branches.—About the middle of the forearm the ulnar nerve gives off two cutaneous branches:—one pierces the fascia and anastomoses with the volar branch of the medial antibrachial (internal) cutaneous nerve, and the other, the **palmar cutaneous branch,** runs downwards in front of the ulnar artery (fig. 683), and is conducted by the vessel into the palm (fig. 680). It furnishes some filaments to the vessel, supplies a few twigs to the skin of the hypothenar eminence, and ends in the integument covering the central depressed surface of the palm.

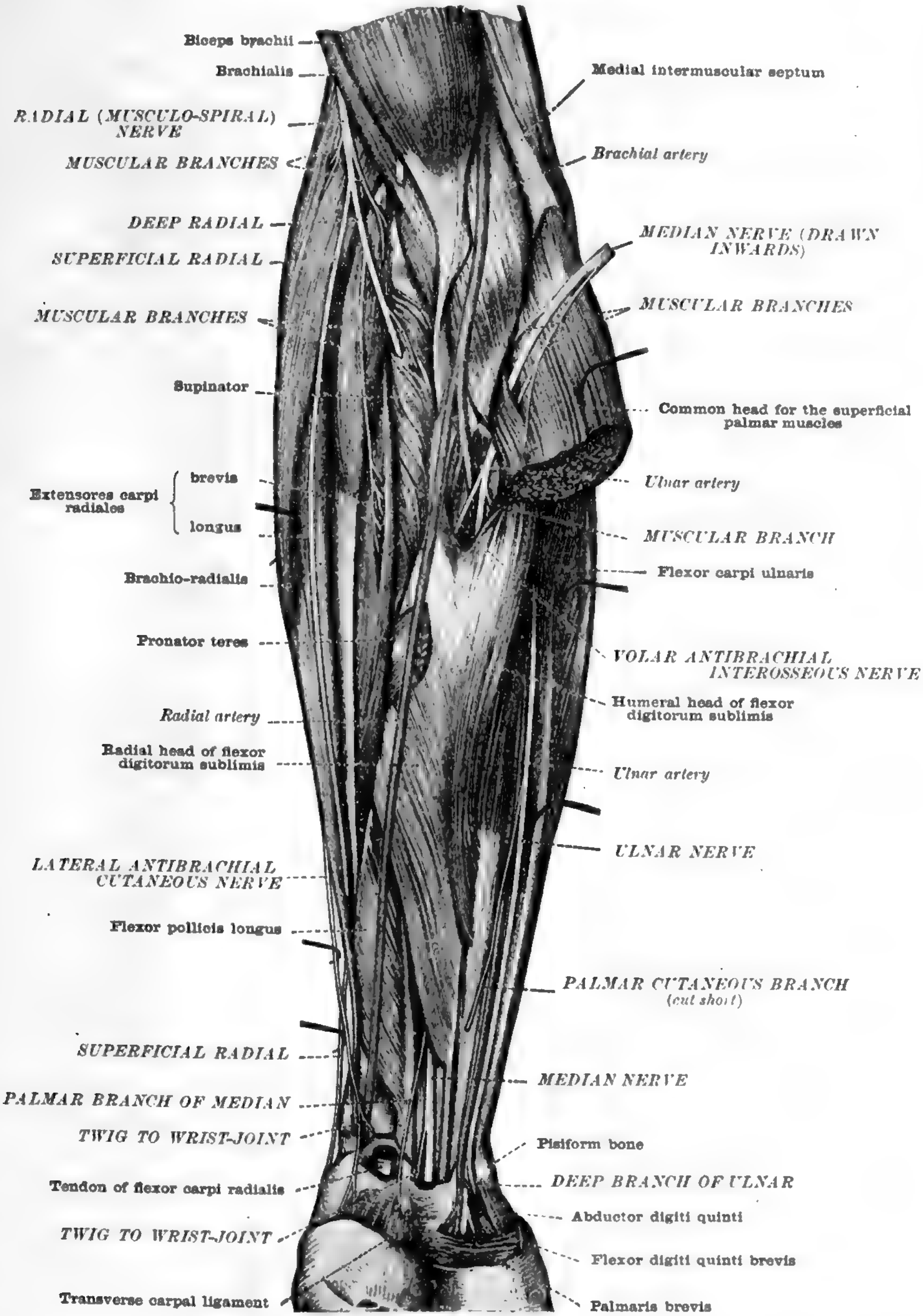
The **dorsal** or **posterior cutaneous branch,** usually the smaller of the terminal branches, arises about 5 cm. (2 in.) above the wrist-joint, and passes backwards under cover of the flexor carpi ulnaris to reach the dorsal aspect of the wrist (fig. 684), where it gives off delicate branches to anastomose with branches of the medial antibrachial (internal) cutaneous, the dorsal antibrachial (external) cutaneous branch of the radial (musculo-spiral), the lateral antibrachial cutaneous of the musculo-cutaneous nerve, and with branches of the superficial radial, and then divides into five branches, the **dorsal digitals** (fig. 681), which are distributed to the ulnar sides of the third, fourth, and fifth digits and the radial sides of the fourth and fifth digits. These branches usually extend on the fifth digit only as far as the base of the terminal phalanx, and on the fourth digit as far as the base of the second phalanx. The more distal parts of these digits are supplied by palmar digital branches of the ulnar nerve.

The **volar branch,** the other terminal branch of the ulnar nerve, continues its course between the flexor carpi ulnaris and flexor digitorum sublimis, on the inner side of the ulnar artery, to the wrist, where, on the outer side of the pisiform bone, it divides into a **superficial** and a **deep branch** (figs. 683 and 684). The latter accompanies the deep branch of the ulnar artery into the interval between the abductor digiti quinti and flexor digiti quinti brevis, and then passes through the fibres of the opponens digiti quinti to reach the deep surface of the flexor tendons and their synovial sheaths. It supplies the abductor and opponens digiti quinti, the flexor digiti quinti brevis, the third and fourth lumbricales, all the interossei, the adductors of the thumb, and the inner head, and occasionally the outer head, of the flexor pollicis brevis. The **superficial branch** gives off a branch to supply the palmaris brevis muscle, an anastomosing branch to the median nerve, and then divides into two branches, the **proper volar digital branch,** which is distributed to the inner side of the fifth digit on its volar aspect, and the **common volar digital branch,** which passes underneath the palmar aponeurosis and divides into two branches, which supply the contiguous margins of the fourth and fifth digits. These branches usually supply also the dorsal surface of the second and third phalanges of the same digits.

The **Median Nerve** contains fibres of the sixth, seventh, and eighth cervical nerves and of the first thoracic, and sometimes of the fifth cervical nerve. The

trunk is formed a little below the lower margin of the pectoralis minor, by the union of two components, one from the inner and one from the outer cord of the plexus (fig. 679). The inner component passes obliquely across the third part of the axil-

Fig. 683.—Deep Nerves of the Volar Surface of the Forearm. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



lary artery, and in the upper part of the trunk the fibres of the two components are felted together. From its commencement the median nerve runs almost vertically through the lower part of the axillary fossa and through the arm. In the

fossa it lies external to the axillary artery and it is overlapped, on its outer side, by the coraco-brachialis muscle. In the upper half of the arm it lies along the outer side of the brachial artery, and it is overlapped by the inner border of the biceps. At the middle of the arm it passes in front of the brachial artery, and then it descends, on the inner side of the artery, to the elbow. In the upper part of the antecubital fossa it is still at the inner side of the brachial artery, but separated from it by a small interval, and in the lower part of the fossa it lies along the inner side of the ulnar artery. As it leaves the antecubital fossa it passes between the two heads of the pronator teres, and it crosses in front of the ulnar artery (fig. 683), from which it is separated by the deep head of the pronator. In the forearm it passes vertically downwards, accompanied by the median (comes nervi mediani) artery. In the upper two-thirds of the region it lies deeply, between the flexor digitorum sublimis and the flexor digitorum profundus, but in the lower third it becomes more superficial, and is placed beneath the deep fascia, between the flexor carpi radialis on the radial side and the palmaris longus and flexor digitorum sublimis tendons on the ulnar side. It crosses beneath the transverse carpal (anterior annular) ligament, in front of the flexor tendons, and in the palm at the lower border of the ligament it enlarges and divides into three branches, the **common volar digital nerves.**

Branches.—The median nerve does not supply any part of the upper arm. In front of the elbow-joint it furnishes one or two filaments to that articulation. In the forearm it supplies all the superficial anterior muscles (with the exception of the flexor carpi ulnaris) directly from its trunk, and it supplies the deep muscles (with the exception of the inner half of the flexor digitorum profundus) by the volar (anterior) interosseous branch. In the hand it supplies the group of short muscles of the thumb which are placed on the radial side of the tendon of the flexor pollicis longus, the two outer lumbricales, the integument covering the central part of the palm and inner part of the thenar eminence, and the palmar aspect of the first, second, third, and radial half of the fourth digits. It also sends twigs to the dorsal aspect of these digits.

The **nerve to the pronator teres** usually arises a little above the bend of the elbow, and pierces the outer border of the muscle (figs. 683 and 684). It may arise in a common trunk with the following nerves:—

The nerves to the **flexor carpi radialis, palmaris longus,** and **flexor digitorum sublimis** arise a little lower down, and pierce the pronator-flexor mass of muscles to end in the respective members of the group for which they are destined (fig. 682).

The **volar (anterior) interosseous nerve** arises from the median at the level of the bicipital tubercle of the radius (fig. 683), and runs downwards, on the interosseous membrane, accompanied by the volar (anterior) interosseous artery. It passes under cover of the pronator quadratus, and pierces the deep surface of that muscle, which it supplies. The volar interosseous nerve also furnishes a twig to the front of the wrist-joint, and supplies the flexor digitorum profundus and the flexor pollicis longus. The nerve to the former muscle arises from the volar interosseous near its commencement; it supplies the outer two divisions of the muscle, and it communicates within the substance of the muscle with twigs derived from the ulnar nerve.

It also supplies a branch to the interosseous membrane which runs downwards upon, or in, the membrane, supplying it and giving branches to the volar (anterior) interosseous and nutrient arteries and to the periosteum of the radius, the ulna, and the carpus.

The **palmar cutaneous branch** arises immediately above the transverse carpal (anterior annular) ligament and passes between the tendons of the flexor carpi radialis and the palmaris longus (fig. 683). It then crosses the superficial surface of the transverse carpal ligament, and is distributed to the integument and fascia on the central depressed surface of the palm. It also supplies a few twigs to the inner border of the thenar eminence; these twigs communicate with the musculo-cutaneous and superficial radial nerves.

The three **common volar digital nerves** pass in the palm of the hand dorsal to the superficial palmar arch and its digital branches, while the **proper volar digitals,** branches of these nerves, lie ventral to the digital arteries.

The **first** of the common volar digital nerves gives off a branch to supply the abductor pollicis, the opponens, and the superficial head of the flexor pollicis brevis, and anastomoses by a delicate branch with the deep branch of the ulnar nerve. It then divides into three **proper volar digitals** (fig. 684). The outer of these passes

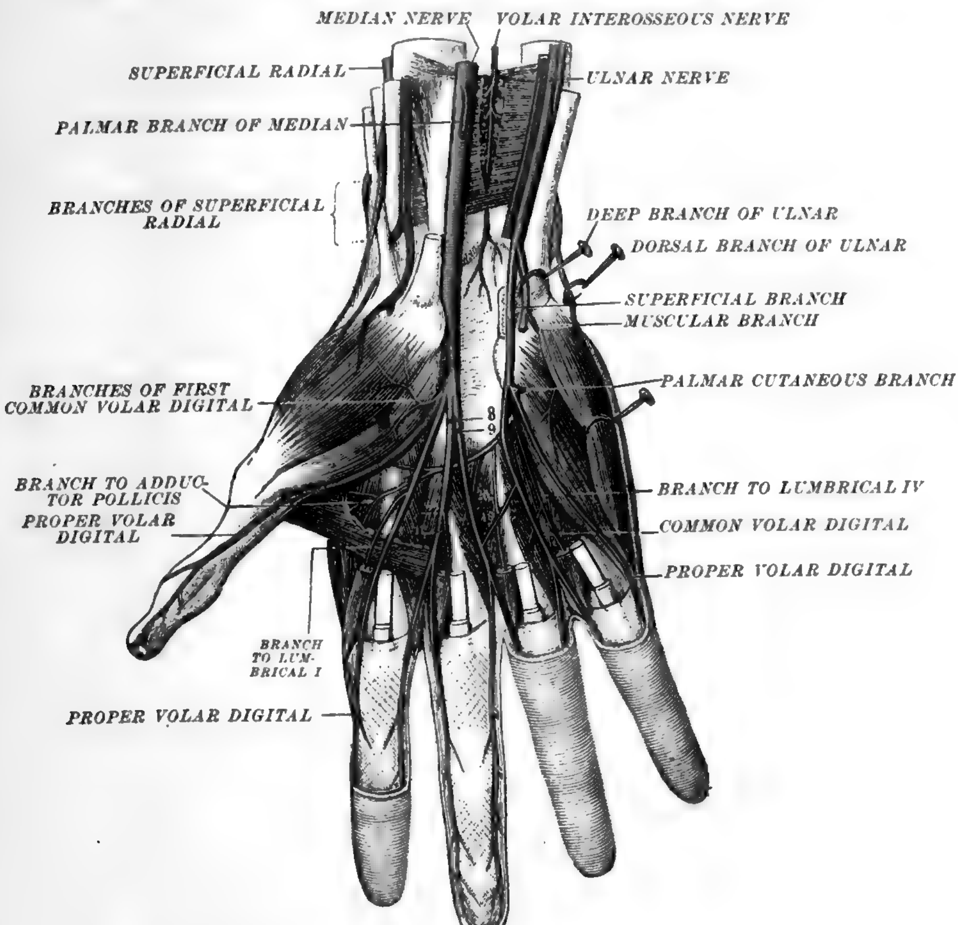
obliquely across the long flexor tendon of the thumb and runs along the radial border of the thumb to its extremity. It gives numerous branches to the pulp of the thumb, and a strong twig which passes to the dorsum to supply the matrix of the nail. The second of these proper volar digitals supplies the ulnar side of the volar aspect of the thumb and gives off a twig to the matrix of the thumb nail. The third supplies the radial side of the second digit and gives a twig to the first lumbrical muscle.

The **second** common volar digital sends a twig to the second lumbrical muscle, and divides a little above the metacarpo-phalangeal articulation into two **proper**

Fig. 684.—Nerves of the Palmar Surface of the Hand. (Testut.)

The transverse carpal (anterior annular) ligament, superficial palmar arch, the flexor tendons of the digits, and the proximal portions of the lumbrical muscles have been removed.

8, 9, Digitals of second and third common volar; 11, branch to lumbrical II; 16, anastomotic branch between ulnar and median nerves; 20, branch to lumbrical III; 22, branch to interossei.



volar digitals, which respectively supply the adjacent sides of the second and third digits.

The **third** common volar digital communicates with the ulnar nerve, often gives a branch to the third lumbrical muscle, and divides into two **proper volar digitals** which supply the adjacent sides of the third and fourth digits.

As the proper volar digitals pass along the margins of the fingers they give off twigs for the innervation of the skin on the dorsum of the second and third phalanges and the matrix of their nails. Each of the nerves terminates in filaments to the pulp of the finger.

TABLE SHOWING RELATION OF CERVICAL AND THORACIC NERVES TO BRANCHES OF BRACHIAL PLEXUS

Nerves Contributing.	Nerves, Branches of Plexus.
5 C.	Dorsal scapular (nerve to rhomboids) Nerve to subclavius
5 and 6 C.	Suprascapular Nerve to subclavius Upper subscapular Lower subscapular Axillary (circumflex)
5, 6, and 7 C.	Long (posterior) thoracic External anterior thoracic
5, 6, and (7) C.	Musculo-cutaneous
(5), 6, 7, 8 C.	Radial (musculo-spiral)
(5), 6, 7, 8 C., and 1 T.	Median
7 and 8 C.	Thoraco-dorsal (middle subscapular)
8 C. and 1 T.	Internal anterior thoracic Ulnar Medial antibrachial (internal) cutaneous
1 T.	Medial brachial (lesser internal) cutaneous

TABLE SHOWING THE RELATIONS OF THE MUSCLES OF THE UPPER EXTREMITY TO THE CERVICAL NERVES

Nerves Contributing.	Muscles.	Nerves to Muscles.
11th cranial, 2 C.	Sterno-mastoid	Spinal accessory
" 3, 4 C.	Trapezius	" " , 3 and 4 C.
3 and 4 C.	Levator scapulæ	3 and 4 C.
5 and 6 C.	Subclavius	Nerve to subclavius
	Supraspinatus Infraspinatus	Suprascapular
	Subscapularis	Upper and lower subscapular
	Teres major	Lower subscapular
	Teres minor Deltoid	Axillary (circumflex)
	Brachialis Biceps	Musculo-cutaneous
6 C.	Brachioradialis	Radial (musculo-spiral)
	Supinator	Deep radial (posterior interosseous)
	Pronator teres	Median
	Flexor carpi radialis	"
	Palmaris longus	"
6 and 7 C.	Ext. carpi radialis longus	Radial (musculo-spiral)
	" " brevis	Deep radial (posterior interosseous)
	Abductor pollicis brevis	Median
	Opponens "	"
	Flexor pollicis brevis (superf. head)	"
5, 6, and 7 C.	Serratus anterior	Long (posterior) thoracic
7 C.	Coraco-brachialis	Musculo-cutaneous
	Ext. digitorum comm.	Deep radial (posterior interosseous)
	" digiti quinti proprius	" " " "
	" carpi ulnaris	" " " "
	Abductor pollicis longus	" " " "
	Extensor pollicis brevis	" " " "
	Extensor pollicis longus	" " " "
	Ext. indicis proprius	" " " "
7 and 8 C	Latissimus dorsi	Thoraco-dorsal (long subscapular)
	Triceps	Radial (musculo-spiral)
	Anconeus	" " "

Table Showing the Relations of the Muscles of the Upper Extremity to the Cervical Nerves—(*Continued*)

Nerves Contributing.	Muscles.	Nerves to Muscles.
5, 6, 7, and 8 C.....	Pectoralis major	Ext. and int. ant. thoracic
8 C...............	Dorsal inteross.	Ulnar
	Palmar "	"
	Add. pollicis	"
	" pollicis trans.	"
	Flex. pollicis brev. (deep)	"
7, 8 C., and 1 T....	Pectoralis minor	Int. ant. thoracic
	Flex. digit. subl.	Median
	Lumbricals	" and ulnar
8 C. and 1 T.......	Flex. carpi ulnaris	Ulnar
	" digit. prof.	" and median
	" pollicis long.	Median
	Pronator quadratus	"

THE THORACIC NERVES

The **anterior primary divisions of the thoracic nerves,** with the exception of the first, retain, in the simplest form, the characters of anterior primary divisions of the typical spinal nerve. They do not form plexuses, but remain distinct from each other. Each divides into an easily recognisable lateral or dorsal and anterior or ventral branch (figs. 685 and 686), and they are not distributed to the limbs. The first, second, and last thoracic nerves, on account of their peculiarities, require separate description. The remainder are separable into two groups, an upper and a lower The **upper group** consists of four nerves, the third to the sixth inclusive, which are distributed entirely to the thoracic wall. The **lower group** contains five nerves, the seventh to the eleventh inclusive, which are distributed partly to the thoracic and partly to the abdominal wall. The upper group is therefore purely thoracic in distribution, and the lower thoraco-abdominal.

The **first thoracic nerve** is connected with the first thoracic sympathetic ganglion, and it frequently receives a communication from the second nerve. It is distributed chiefly to the upper limb. Opposite the superior costo-transverse ligament of the second rib it divides into a larger and a smaller branch; the larger passes upwards and outwards, between the apex of the pleura and the neck of the first rib, and on the outer side of the superior intercostal artery, to the root of the neck, where it joins the brachial plexus. The smaller branch continues along the intercostal space, below the first rib and between the intercostal muscles in which, as a rule, all its fibres terminate. However, in some instances it gives off a lateral cutaneous branch which connects with the medial brachial (lesser internal) cutaneous nerve and with the intercosto-brachial nerve in the axillary fossa; and occasionally it terminates in an anterior cutaneous branch at the anterior extremity of the first intercostal space.

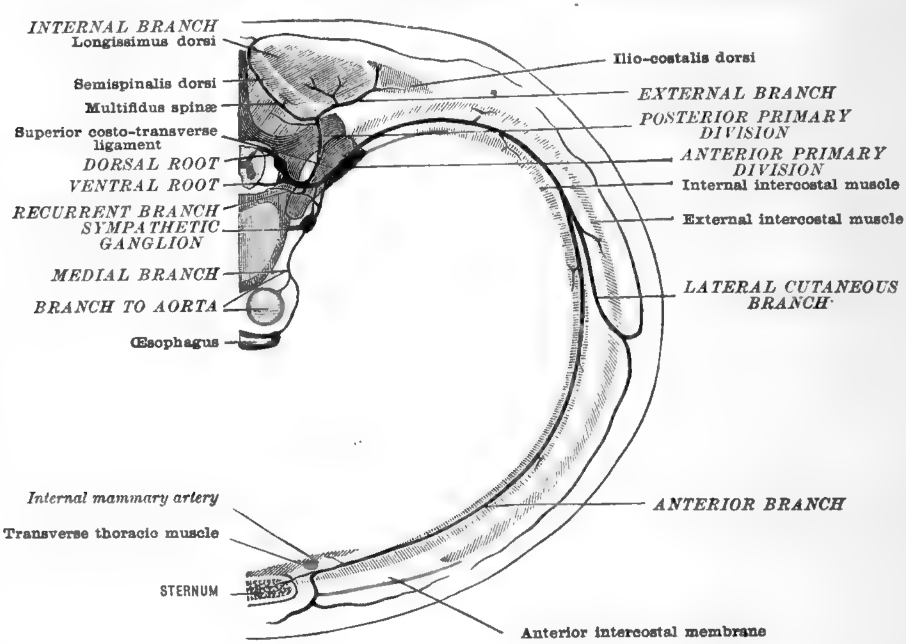
The **second thoracic nerve,** as it lies between the pleura and the superior costo-transverse ligament of the third rib, gives a branch to the first nerve, then it pierces the posterior intercostal membrane and passes between the external and internal intercostal muscles in the second intercostal space. In the posterior part of the space it sends branches backwards, through the external intercostal muscle, to supply the second levator costæ and the serratus posterior superior, and then it divides into a *lateral* and an *anterior* branch. The two branches run forward together to the mid-axillary line, where the lateral branch pierces the external intercostal muscle and passes between two digitations of the serratus anterior (magnus) into the axillary fossa; the anterior branch enters the substance of the internal intercostal muscle.

The **lateral branch,** the **intercosto-brachial** (*intercosto-humeral*), may divide into a small anterior and a large posterior division, or the anterior division may be absent. In either case the lateral branch anastomoses with the medial brachial (lesser internal) cutaneous nerve, and usually with the lateral branch of the third intercostal nerve; it also anastomoses with the lateral branch of the first nerve, if the latter is present. After forming these anastomoses it passes out of the axillary fossa, pierces the deep fascia, and supplies the integument in the upper and posterior half of the arm. It also gives off a few filaments which terminate in the skin over the axillary border of the scapula. The size of the intercosto-brachial nerve and the extent of its distribution are usually in inverse proportion to the size of the other cutaneous nerves of the upper arm, especially the middle brachial (lesser internal) cutaneous. When the latter nerve is absent, the intercosto-brachial usually takes its place.

The course and distribution of the *anterior branch,* when it is present, being similar to the course and distribution of the anterior branches of the next four nerves, do not require a separate description.

The **thoracic intercostal nerves.**—The third, fourth, fifth, and sixth thoracic nerves, in the posterior parts of the intercostal spaces, give **muscular branches** to the

Fig. 685.—Diagram of the Distribution of a Typical Thoracic Nerve.



levatores costarum, the second and sometimes the third also giving branches to the serratus posterior superior. They pass forwards a short distance between the external and internal intercostals, giving twigs to these muscles, and divide into two branches, lateral and anterior.

The **lateral cutaneous branches** continue forwards between the intercostal muscles, and, near the mid-axillary line, pierce the external intercostals and serratus anterior (magnus) and divide into two branches, posterior and anterior. The *posterior branches* pass backwards over the latissimus dorsi to supply the skin in the lower part of the scapular region. The *anterior branches* increase in size from above downwards. They pass around the outer border of the great pectoral muscle, and are distributed to the integument over the front of the thorax and mamma, sending filaments, the *lateral mammary branches*, into the latter organ. The lowest two also supply twigs to the upper digitations of the external oblique muscle.

The **anterior branches** run obliquely forwards and inwards, through the substance of the internal intercostal muscles, reaching the deep surface of these muscles at the outer extremity of the costal cartilages (fig. 685). They continue forwards between these muscles and the pleura, pass in front of the internal mammary artery,

turn abruptly ventral a short distance from the sternum, pierce the internal intercostals, the anterior intercostal membrane, and the pectoralis major, and give off three sets of terminal branches. One set supplies the transverse thoracic muscle and the back of the sternum. A second set, cutaneous, runs mesially. The third set passes laterally over the pectoralis major, supplying the skin in that region, and, in the female, the mammary gland through the **medial mammary branches**. The anterior branches in their course supply the intercostal and subcostal muscles and give filaments that supply the ribs, the periosteum, and the pleura.

The thoraco-abdominal nerves.—The relations of the posterior portions of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves to the thoracic wall are similar to those of the thoracic intercostal nerves. Each divides in a similar manner into a lateral and an anterior branch, but these branches are distributed partly to the abdominal and partly to the thoracic wall, and the smaller muscular branches have also different distributions.

The **lateral branches,** *lateral cutaneous nerves of the abdomen*, pierce the external intercostal muscles and pass through or between the digitations of the external oblique into the subcutaneous tissue, where they divide in the typical way into anterior and posterior branches. The *posterior branches* pass backwards over the latissimus dorsi. The *anterior branches* give filaments to the digitations of the external oblique and extend forwards, inwards, and downwards to the outer border of the sheath of the rectus.

The **anterior branches** pass forwards between the external and internal intercostal muscles, to the anterior ends of the intercostal spaces; there they insinuate themselves between the interdigitating slips of the diaphragm and the transversus abdominis and enter the abdominal wall. The seventh, eighth, and ninth nerves, in their transit from the thoracic to the abdominal wall, pass behind the upturned ends of the eighth, ninth, and tenth rib-cartilages respectively. Having entered the abdominal wall the nerves run forwards between the transversus abdominis and the internal oblique muscles to the outer border of the rectus abdominis, where they pierce the posterior lamella of the internal oblique aponeurosis and enter the sheath of the rectus. In the sheath they pass through the substance of the rectus. Finally they turn directly forwards, pierce the anterior part of the sheath, and become **anterior cutaneous nerves of the abdomen.**

The muscular branches.—Muscular branches are distributed to the levatores costarum, the intercostal muscles, the transversus abdominis, the internal oblique, and to the rectus abdominis from all the thoraco-abdominal nerves, and the ninth, tenth, and eleventh nerves give branches to the serratus posterior inferior. Branches are also distributed from a variable number of the lower nerves to the costal portions of the diaphragm.

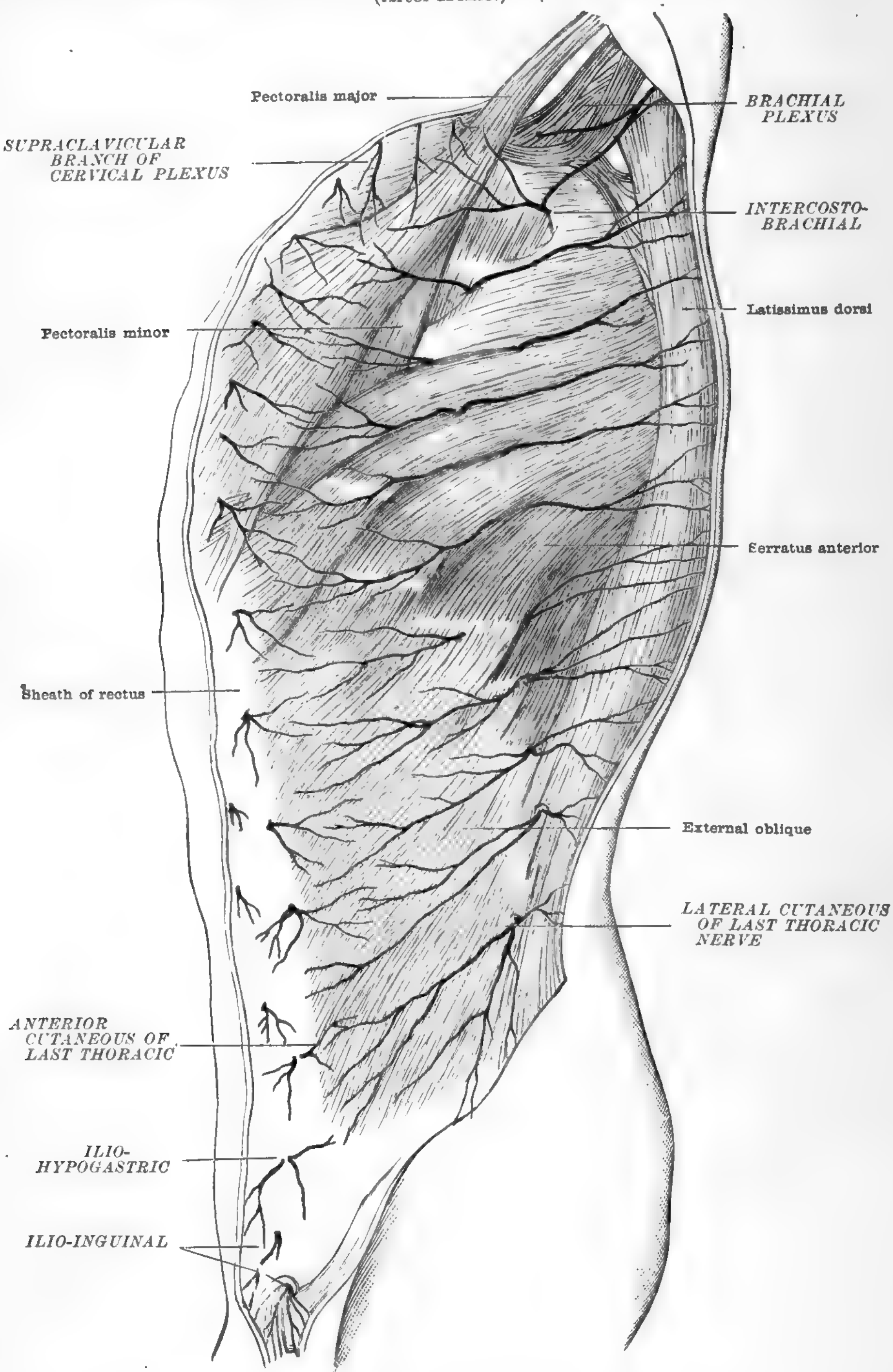
The last thoracic nerve.—The anterior primary division of the last thoracic nerve is distributed to the wall of the abdomen and to the skin of the upper and front part of the buttock. It appears in the thoracic wall immediately below the last rib, where it communicates with the sympathetic cord and gives off a communicating branch, the first lumbar nerve. It passes from the thorax into the abdomen beneath the lateral lumbo-costal arch (external arcuate ligament), accompanied by the subcostal artery, and it runs across the upper part of the quadratus lumborum behind the kidney and the ascending or the descending colon according to the side in which it lies. At the outer border of the quadratus lumborum it pierces the aponeurosis of origin of the transversus abdominis muscle and divides, between the transversus and the internal oblique muscle, into a lateral and an anterior branch. It gives branches to the transversus abdominis, the quadratus lumborum, and the internal oblique muscles.

The **anterior branch** passes forwards, between the internal oblique and the transversus abdominis, to which it supplies twigs. It enters the sheath of the rectus, turns forwards through that muscle, and terminates in branches which become cutaneous midway between the umbilicus and the symphysis. Before it becomes cutaneous it supplies twigs to the transversus abdominis, the internal oblique, the rectus abdominis, and the pyramidalis muscles.

The **lateral branch** pierces the internal oblique; it supplies the lowest digitation of the external oblique, and then pierces the latter muscle from 2·5 to 8 cm. (1 to 3 in.) above the iliac crest, and descends in the superficial fascia of the anterior part of the gluteal region, crossing the iliac crest about 2·5 cm. (1 in.) behind its an-

terior extremity and reaching as far down as the level of the great trochanter. Occasionally this branch is absent and its place is taken by the iliac branch of the ilio-

Fig. 686.—Cutaneous Nerves of the Thorax and Abdomen, viewed from the Side. (After Henle.)



hypogastric. In such cases, however, the communicating branch from the last thoracic to the first lumbar nerve is larger than usual.

THE LUMBO-SACRAL PLEXUS

The lumbo-sacral plexus is formed by the union of the anterior primary divisions of the lumbar, sacral, and coccygeal nerves. In about 50 per cent. of cases it receives a branch from the twelth thoracic nerve.

Partly for convenience of description and partly on account of the differences in position and course of some of the nerves arising from it this plexus is subdivided into four parts—the lumbar, sacral, pudendal, and coccygeal plexuses. These plexuses overlap so that there is no definite line of demarcation between them. However, they will be considered separately.

THE LUMBAR NERVES

The anterior primary divisions of the five lumbar nerves increase in size from the first to the last. Each lumbar nerve is connected by one or two long, slender branches with a lumbar sympathetic ganglion. The first three and the greater part of the fourth enter into the formation of the lumbar plexus, and the smaller part of the fourth and the fifth nerve commonly unite to form the lumbo-sacral cord which takes part in the formation of the sacral plexus (figs. 687 and 688). When the fourth nerve enters into the formation of both lumbar and sacral plexuses, it may be called the *furcal nerve*, but this name is also applied to any of the nerves that enter into the formation of both plexuses, so there may be one or more furcal nerves.

THE LUMBAR PLEXUS

Although the **lumbar plexus** is ordinarily formed by the first three lumbar nerves and a part of the fourth, yet it is subject to considerable variation in the manner of its formation. Owing to this variation three general classes of plexuses may be found, **proximal** or **pre-fixed, ordinary,** and **distal** or **post-fixed.** The basis of classification is the relation of the nerves of the limb to the spinal nerves which enter into their formation. The intermediate or slighter degrees of variation may consist only of changes in the size of the portions contributed by the different spinal nerves to a given peripheral nerve, for a given nerve may receive a larger share of its fibres from a more proximal spinal nerve, and a smaller share from a more distal nerve, or *vice versâ.* However, in the more marked degrees of variation the origin of a given peripheral nerve may vary in either direction to the extent of one spinal nerve. The more extreme types of the plexuses are sometimes associated with abnormal conditions of the vertebral column. It has been suggested that when the prefixed or proximal condition occurs, it indicates that the lower limb is placed a segment more proximal than in the ordinary cases, and when the distal condition is present, that the limb is arranged a segment more distal. Three types each of the proximal and the distal classes and one type of the ordinary class have been described by Bardeen. His statistics are made use of in the compilation of the following tables, in which are shown the range of variation and the common composition of each class:—

Composition of the Nerves of the Lumbar Plexus

Range of Variation

Nerve.	Proximal.	Ordinary.	Distal.
Lateral (external) cutaneous	12 T, 1, 2, 3 L.	1, 2, 3, 4 L.	1, 2, 3, 4 L.
Femoral (anterior crural)	12 T, 1, 2, 3, 4 L.	1, 2, 3, 4 L.	1, 2, 3, 4, 5 L.
Obturator	1, 2, 3, 4 L.	1, 2, 3, 4 L.	2, 3, 4, 5 L.
Furcal	3 or 3, 4 L.	4 L.	4, 5 or 5 L.

Common Composition

Nerve.	Proximal.	Ordinary.	Distal.
Lateral (external) cutaneous	1, 2 L.	1, 2, 3 L.	2, 3 L.
Femoral (anterior crural) . .	1, 2, 3, 4 L.	2, 3, 4 L.	2, 3, 4, 5 L.
Obturator	1, 2, 3, 4 L.	2, 3, 4 L.	2, 3, 4 L.
Furcal	4 L.	4 L.	4 L.

The lumbar plexus lies in the posterior part of the psoas muscle (fig. 688), in front of the transverse processes of the lumbar vertebræ and the inner border of the quadratus lumborum, and its terminal branches are distributed to the lower part of the abdominal wall, the front and inner part of the thigh, the external genital organs, the front of the knee, the inner side of the leg, and the inner side of the foot.

The first and second of the nerves give collateral *muscular branches* to the quadratus lumborum muscle, and the second and third nerves give similar branches to the psoas. The remaining branches of the plexus are *terminal branches.* The first lumbar nerve, after it has been joined by the communication from the last thoracic nerve, divides into three terminal branches, the ilio-hypogastric nerve, the ilio-inguinal nerve, and a branch which joins the second nerve. The fibres of this latter branch pass mainly into the genito-femoral (genito-crural) nerve, but occasionally some of them enter the femoral (anterior crural) and obturator nerves. The remaining nerves divide into anterior or ventral and posterior or dorsal divisions. The **anterior divisions** form a portion of the genito-femoral (genito-crural) nerve and the obturator nerve, and the **posterior divisions** enter the lateral (external) cutaneous and femoral (anterior crural) nerves.

All the terminal branches of the plexus are formed in the substance of the psoas muscle; four of them, the ilio-hypogastric, the ilio-inguinal, the lateral (external) cutaneous, and the femoral (anterior crural), leave the muscle at its outer border. The genito-femoral (genito-crural) passes through its anterior surface, and the obturator through its inner border.

Terminal branches.—The **Ilio-hypogastric Nerve** springs from the first lumbar nerve, after the latter has been joined by the communicating branch from the last thoracic nerve, as it is in about 50 per cent. of the cases, and it contains fibres of both the last thoracic and the first lumbar nerves. It pierces the outer border of the psoas and crosses in front of the quadratus lumborum (fig. 688), and behind the kidney and the colon. At the outer border of the quadratus it pierces the aponeurosis of origin of the transversus abdominis and enters the areolar tissue between the transversus and the internal oblique, where it frequently communicates with the last thoracic and with the ilio-inguinal nerve, and it divides into an iliac and a hypogastric branch, which correspond, respectively, with the lateral and anterior branches of a typical spinal nerve. The **anterior cutaneous (hypogastric) branch** passes forwards and downwards, between the transversus abdominis and the internal oblique muscles, giving branches to both; it communicates with the ilio-inguinal nerve, and, near the anterior superior spine of the ilium, it pierces the internal oblique muscle and continues forwards beneath the external oblique aponeurosis towards the middle line. About 2·5 cm. (1 in.) above the subcutaneous inguinal ring it pierces the aponeurosis of the external oblique, becomes subcutaneous, and supplies the skin above the symphysis.

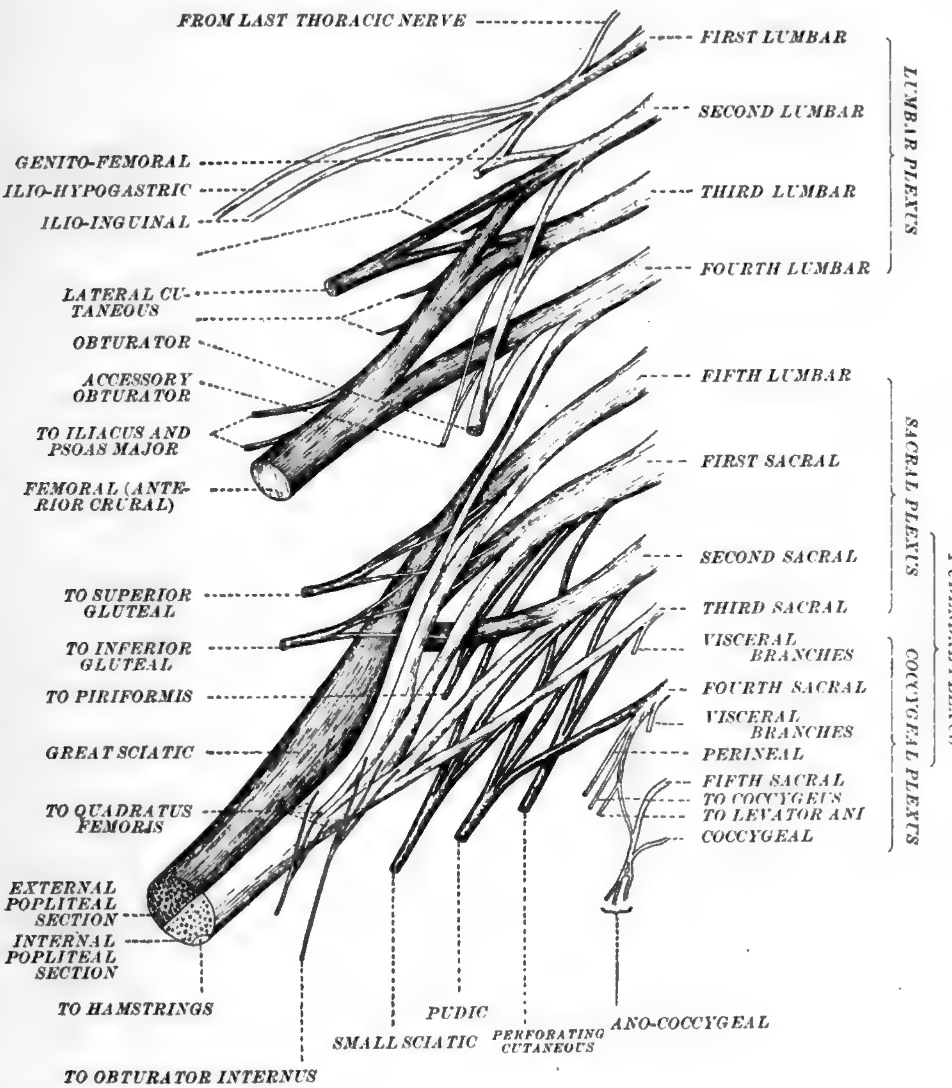
The **lateral cutaneous (iliac) branch** pierces the internal and external oblique muscles, emerging through the latter above the iliac crest at the junction of its anterior and middle thirds (fig. 693). It is distributed to the integument of the upper and outer part of the thigh, in the neighbourhood of the gluteus medius and tensor fasciæ latæ muscles (fig. 691).

The **Ilio-inguinal Nerve** arises principally from the first lumbar nerve, but it frequently contains fibres of the last thoracic nerve. It emerges from the outer border of the psoas, at a lower level than the ilio-hypogastric nerve, and passes across the quadratus lumborum (figs. 688 and 689). As a rule, it is below the level of the lower end of the kidney, but it passes behind the ascending or the descending colon according to the side on which it lies, and crosses the posterior part of the inner lip of the iliac crest; it then runs forwards on the upper part of the iliacus, pierces the transversus abdominis near the anterior part of the crest, and communicates with the anterior cutaneous (hypogastric) branch of the ilio-hypogastric

nerve. A short distance below the anterior superior spine it passes through the internal oblique muscle, and then descends in the inguinal canal to the subcutaneous inguinal (external abdominal) ring, through which it emerges into the thigh on the outer side of the spermatic cord (fig. 686). It is distributed to the skin of the upper and inner part of the thigh, in the male to the root of the penis and to the skin of the root of the scrotum through the **anterior scrotal nerves** (fig. 691), and in the female to the mons veneris and labium majus through the **anterior labial nerves.**

Not uncommonly the ilio-inguinal nerve is blended with the ilio-hypogastric nerve

Fig. 687.—Diagram of a Common Form of Lumbo-sacral Plexus. (Modified from Paterson.)



and separates from the latter between the transversus abdominis and the internal oblique muscles. It may be replaced by branches of the genito-femoral (genito-crural) nerve, or it may replace that nerve or the lateral cutaneous nerve.

The **Genito-femoral (genito-crural) Nerve** is connected with the first and second lumbar nerves, but the majority of its fibres are derived from the second nerve. It passes obliquely forwards and downwards through the psoas and emerges from the anterior surface of that muscle, close to its internal border, at the level of the lower border of the third lumbar vertebra. After emerging from the substance of the

psoas it runs downwards on the anterior surface of the muscle (fig. 688), to the outer side of the aorta and the common iliac artery, passes behind the ureter and divides into two branches, an external spermatic or genital, and a lumbo-inguinal or crural (fig. 689). Occasionally it divides in the substance of the psoas, and then the two branches issue separately through the anterior surface of the muscle.

The **external spermatic (genital) branch** runs downwards on the psoas muscle, external to the external iliac artery; it gives a branch to the psoas, and at Poupart's ligament it turns around the inferior epigastric artery and enters the inguinal canal, accompanying the spermatic cord in the male or the round ligament in the female. It supplies the cremaster muscle, and gives twigs to the integument of the scrotum (fig. 689) or the labium majus.

The **lumbo-inguinal (crural) branch** passes downwards along the external iliac artery and beneath Poupart's ligament into the thigh, which it enters to the outer side of the femoral artery. A short distance below Poupart's ligament it pierces the fascia lata or passes through the fossa ovalis (saphenous opening) and supplies the skin in the middle of the upper part of the thigh. A short distance below Poupart's ligament it sometimes sends branches of communication to the anterior branch of the lateral cutaneous nerve, and about the middle of the thigh it often communicates with the cutaneous branches of the femoral (anterior crural) nerve.

The **Lateral Cutaneous Nerve** receives fibres from the dorsal branches of the anterior primary divisions of the second and third lumbar nerves, and frequently some fibres from the first lumbar (fig. 693). It emerges from the outer border of the psoas and passes obliquely across the iliacus behind the iliac fascia, and behind the cæcum on the right side and the sigmoid colon on the left side, to a point immediately below the anterior superior spine of the ilium, where it passes below Poupart's ligament into the outer angle of the femoral trigone (Scarpa's triangle). Leaving the trigone at once it passes through, behind, or in front of the sartorius and divides into two branches, anterior and posterior, which enter the deep fascia (fig. 689).

The **posterior branch** of the lateral cutaneous nerve breaks up into several secondary branches which become subcutaneous, and they supply the integument of the outer part of the thigh, from the great trochanter to the level of the middle of the femur. The **anterior branch** runs downwards in a canal in the deep fascia, for three or four inches, before it becomes subcutaneous. It usually divides into two branches, an external and an internal. The *external branch* supplies the skin of the lower half of the outer side of the thigh, and the *internal branch* is distributed to the skin of the outer side of the front of the thigh as far as the knee (fig. 689). Its lower filaments frequently unite with the cutaneous branches of the femoral (anterior crural), and with the patellar branch of the saphenous nerve in front of the patella, forming with them the **patellar plexus.**

The **Femoral (Anterior Crural) Nerve** is the largest branch of the lumbar plexus. It is formed principally by fibres of the dorsal branches of the anterior primary divisions of the second, third, and fourth lumbar nerves, but it sometimes receives fibres from the first nerve also (figs. 688 and 693). It emerges from the outer border of the psoas a short distance above Poupart's ligament, and descends in the groove between the psoas and the iliacus, behind Poupart's ligament, into the femoral trigone (Scarpa's triangle), where it lies to the outer side of the femoral artery (fig. 690), from which it is separated by some of the fibres of the psoas. In this situation it is flattened out and it divides into two series of terminal branches, the superficial and the deep.

Branches.—The branches are collateral and terminal.

The **collateral branches** are twigs of supply to the iliacus, and a branch to the femoral artery; they are given off before the nerve enters the femoral trigone.

The **terminal branches** form two groups, the superficial and the deep.

The **superficial terminal branches** are two muscular branches, the nerve to the pectineus, and the nerve to the sartorius, and two anterior cutaneous branches.

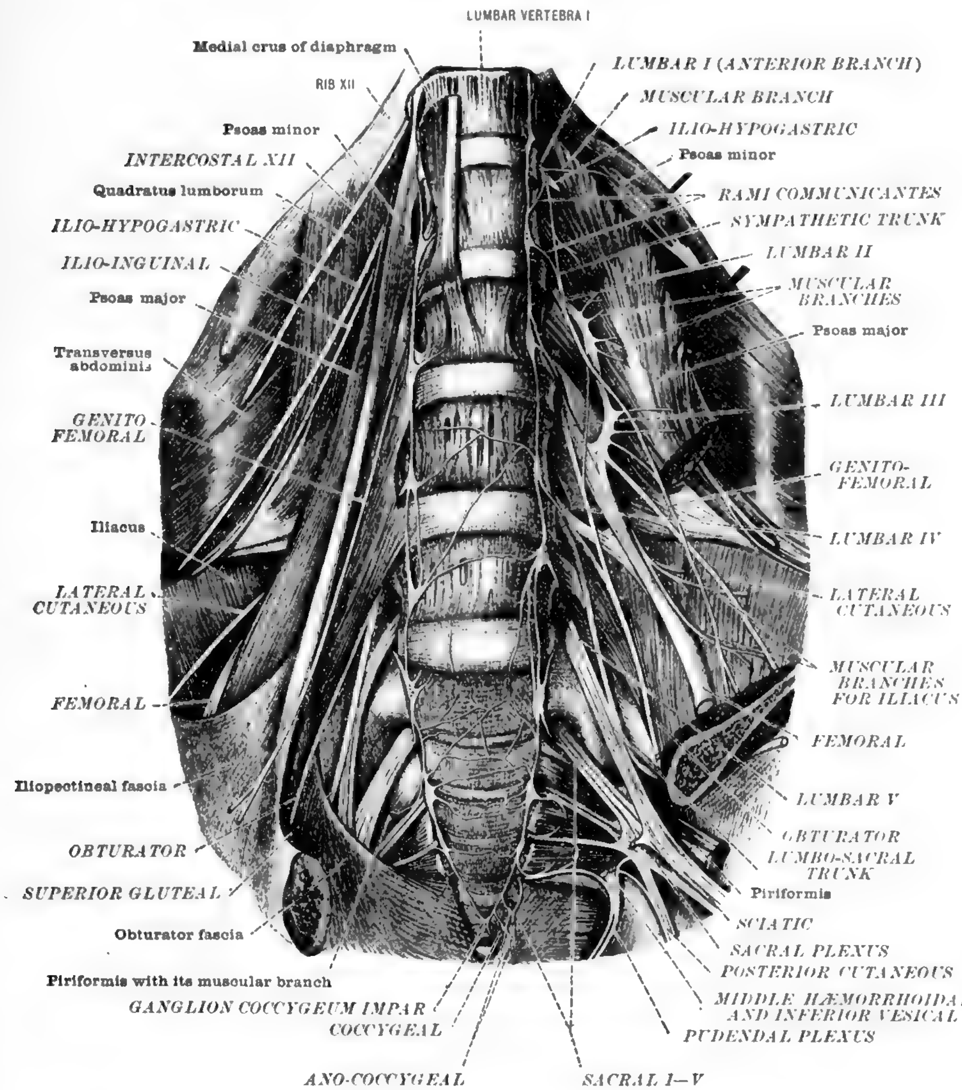
The **nerve to the pectineus** passes inwards and downwards behind the femoral sheath and in front of the psoas to the anterior surface of the pectineus, in which it terminates.

The **nerve to the sartorius** accompanies the middle cutaneous nerve; it leaves the latter nerve above the sartorius and ends in the upper part of the muscle.

The **anterior (middle and internal) cutaneous nerves** are best described separately. The **middle cutaneous nerve** soon divides into two branches, inner and outer.

The outer branch pierces the sartorius and both become cutaneous about the junction of the upper and middle thirds of the thigh (figs. 689 and 691). They descend along the inner part of the front of the thigh to the knee, supplying the skin in the lower two-thirds of the inner part of the front of the thigh, and their terminal filaments take part in the formation of the patellar plexus. About the middle of the thigh it often communicates with the lumbo-inguinal nerve (crural branch of the genito-crural nerve). The **internal cutaneous nerve** runs downwards and inwards

Fig. 688.—Lumbo-sacral Plexus. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)

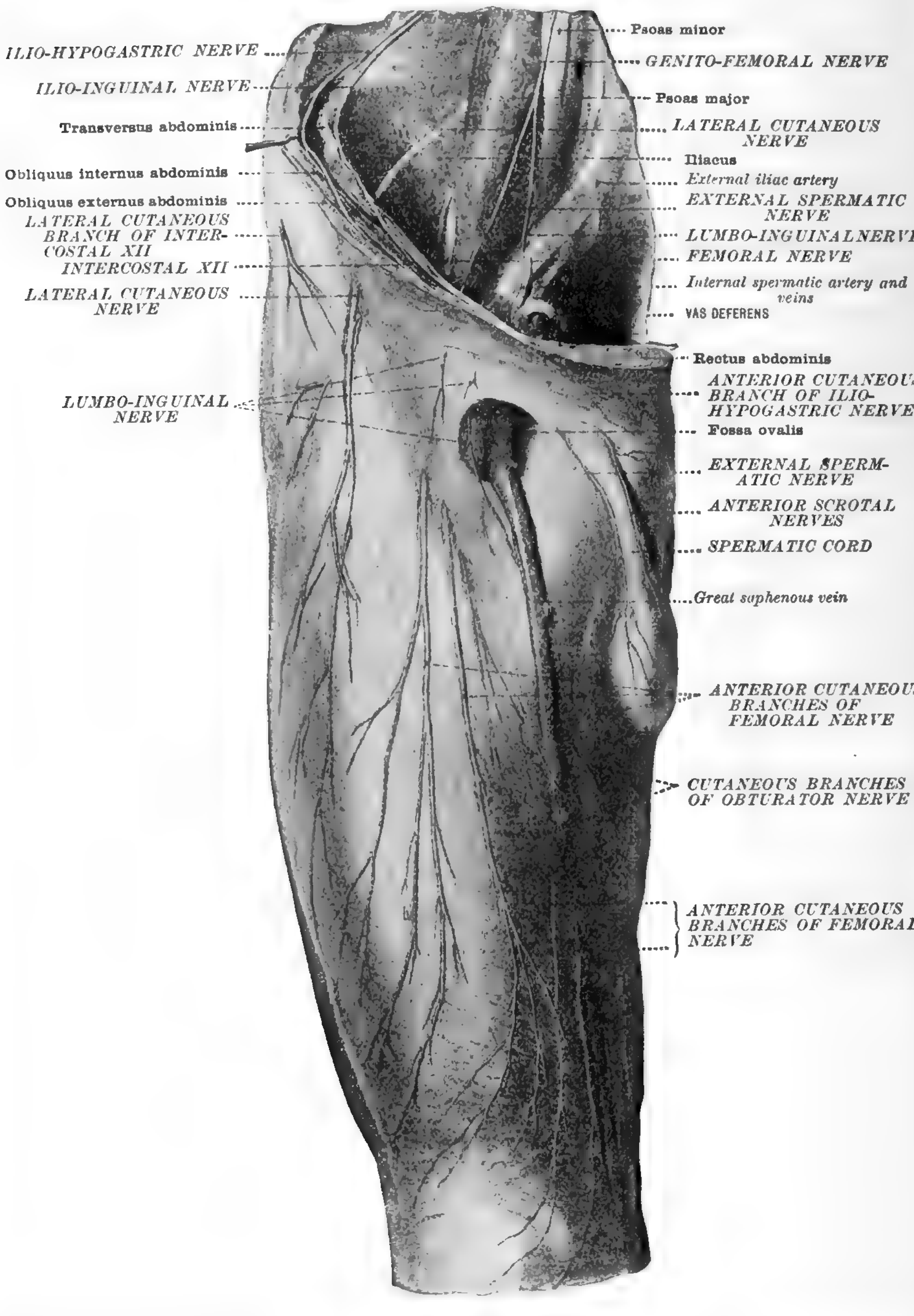


along the outer side of the femoral artery, to the apex of the femoral trigone (Scarpa's triangle), where it crosses in front of the artery and divides into an anterior and a posterior terminal branch. Before this division takes place, however, two or three collateral branches are given off from the trunk. The highest of these passes through the fossa ovalis (saphenous opening), or it pierces the deep fascia immediately below the opening, and supplies the skin as low as the middle of the thigh. The lowest pierces the deep fascia at the middle of the thigh and it descends in the subcutaneous tissue, supplying the skin on the inner side of the thigh from the middle of the thigh

to the knee (figs. 691 and 693). This nerve frequently varies in size inversely with the cutaneous branches of the obturator and saphenous nerves.

The **anterior branch** passes vertically downwards to the junction of the middle

FIG. 689.—CUTANEOUS NERVES OF THE RIGHT THIGH. (Spalteholz.)
(The iliac fascia has been removed, the fascia lata retained.)



and lower thirds of the thigh, where it pierces the deep fascia. It still continues downwards for a short distance, then it turns outwards and passes to the front of the knee, where it enters into the patellar plexus.

The **posterior branch** descends along the posterior border of the sartorius, and it gives off a branch which passes beneath that muscle to unite with twigs from the saphenous and from the superficial division of the obturator nerve, forming with them the **subsartorial plexus** which lies on the roof of the adductor (Hunter's)canal. At the inner side of the knee the nerve pierces the deep fascia and it descends to the middle of the calf (figs. 689 and 691).

The **deep terminal branches** are six in number, one cutaneous branch, the saphenous, and five muscular branches. The branches radiate from the termination of the trunk of the femoral (anterior crural) nerve, and they are arranged in the following order from within outward:—the saphenous nerve, the nerve to the vastus medialis, the nerve to the articularis genu (subcrureus), the nerve to the vastus intermedius (crureus), the nerve to the vastus lateralis, and the nerve to the rectus femoris.

The **saphenous nerve** passes down through Scarpa's triangle along the outer side of the femoral artery. At the apex of the triangle it enters the adductor (Hunter's) canal and descends through it, lying first to the outer side, then in front, and finally to the inner side of the artery (fig. 690). After emerging from the lower end of the canal, accompanied by the superficial branch of the genu suprema (anastomotic) artery, it passes between the posterior border of the sartorius and the anterior border of the tendon of the gracilis, and, becoming superficial, it enters into relationship with the great saphenous vein and descends with it along the inner border of the upper two-thirds of the tibia (fig. 691). It crosses the inner surface of the lower third of the tibia, passes in front of the internal malleolus, and runs forwards along the inner border of the foot to the ball of the great toe.

While it is in the adductor (Hunter's) canal it gives off a twig to the subsartorial plexus. Before it passes from under cover of the sartorius it gives off an infrapatellar branch, which pierces the sartorius just above the knee and passes outwards to the patellar plexus. After it becomes superficial it supplies the integument on the inner side of the leg and foot, and it anastomoses, in the foot, with the medial dorsal cutaneous branch of the superficial peroneal (musculo-cutaneous) nerve.

The **nerve to the vastus medialis** accompanies the saphenous nerve in the femoral trigone (Scarpa's triangle), lying to its outer side. At the upper end of the adductor canal it passes beneath the sartorius, external to the roof of the canal, and enters the inner surface of the vastus medialis. It sends a twig down to the knee-joint.

The **nerve to the articularis genu (subcrureus),** usually a terminal branch of the femoral, frequently arises from the nerve to the vastus intermedius. It passes between the vastus medialis and the vastus intermedius to the lower third of the thigh, where it supplies the articularis genu and sends a branch to the knee-joint.

The **nerve to the vastus intermedius** (**crureus**) is represented by two or three branches which enter the upper part of the muscle. One of them frequently sends a twig to the knee-joint.

The **nerve to the vastus lateralis** passes downwards behind the rectus and along the anterior border of the vastus lateralis accompanied by the descending branch of the external circumflex artery. It also sends a branch to the knee-joint.

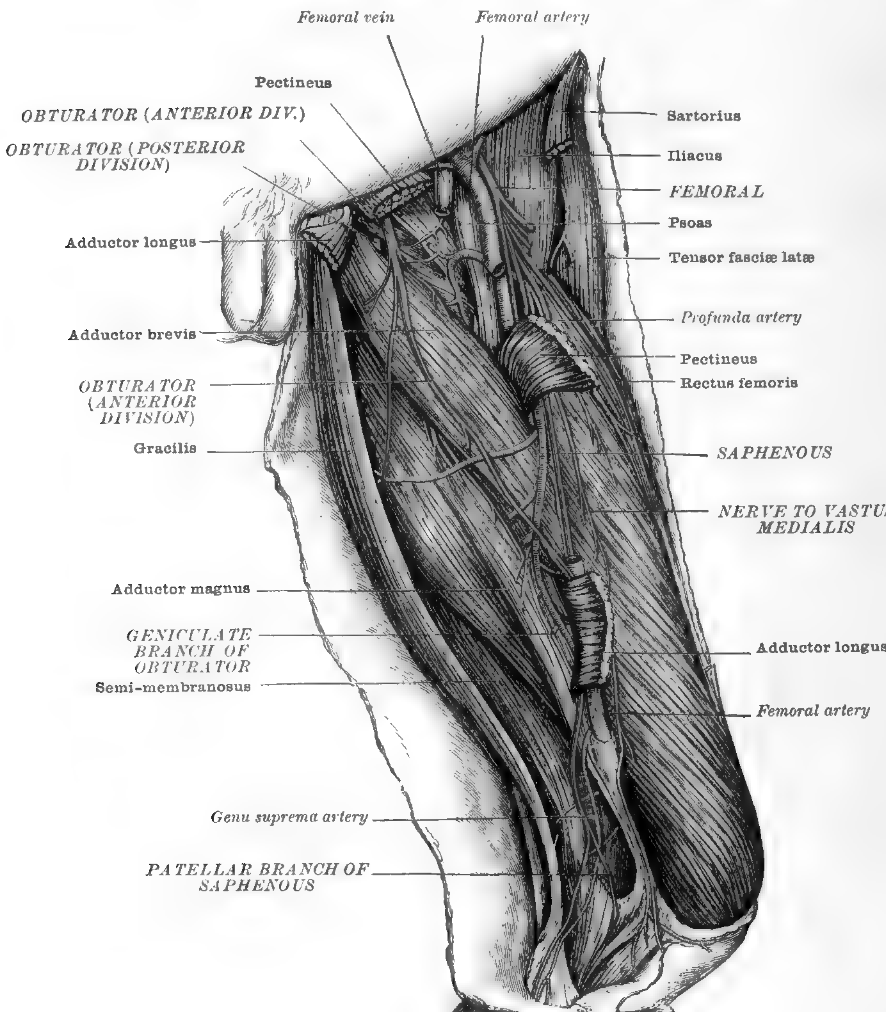
The **nerve to the rectus femoris** (fig. 690) enters the deep surface of that muscle, having previously given off a twig to the hip-joint which accompanies the ascending branch of the external circumflex artery.

The **Obturator Nerve** contains fibres from the anterior divisions of the second, third, and fourth lumbar nerves, but its largest root is derived from the third nerve (figs. 688 and 693). It sometimes receives fibres from the first and third lumbar nerves. It emerges from the inner border of the psoas at the posterior part of the brim of the pelvis, where it lies in close relation with the lumbo-sacral trunk of the plexus, from which it is separated by the ilio-lumbar artery. Immediately after its exit from the psoas it pierces the pelvic fascia, crosses the outer side of the internal iliac vessels and the ureter, and runs forwards in the extraperitoneal fat, below the obliterated hypogastric artery and along the upper part of the inner surface of the obturator internus to the upper part of the obturator foramen, where it passes through the obturator canal below the so-called horizontal ramus of the pubis and above the obturator membrane, into the upper part of the thigh. It is accompanied in the pelvis and the obturator canal by the obturator artery, which lies at a lower level than the nerve, and it divides in the obturator canal into two branches, an anterior and a posterior.

The **anterior branch** forms a communication with the accessory obturator nerve, if that nerve is present, and then descends behind the pectineus and adductor longus and in front of the obturator externus and adductor magnus muscles (fig. 690). Its branches are:—

1. A **communicating twig** to the accessory obturator nerve if the latter is present.
2. An **articular branch** to the hip-joint.
3. **Muscular branches** to the gracilis, adductor longus, and, usually, to the adductor brevis.
4. Two **terminal branches,** of which one is distributed to the femoral artery and the other communicates with the subsartorial plexus. The subsartorial branch

Fig. 690.—Anterior Crural and Obturator Nerves. (Ellis.)



is occasionally longer than usual, and it then descends, along the posterior border of the sartorius, to the inner side of the knee, where it enters the subcutaneous tissue, and, proceeding downwards, supplies the skin on the inner side of the leg as far as the middle of the calf. It anastomoses with the saphenous.

The **posterior branch** (fig. 690) pierces the upper part of the obturator externus and passes downwards between the adductor brevis and adductor magnus. Its branches are:—

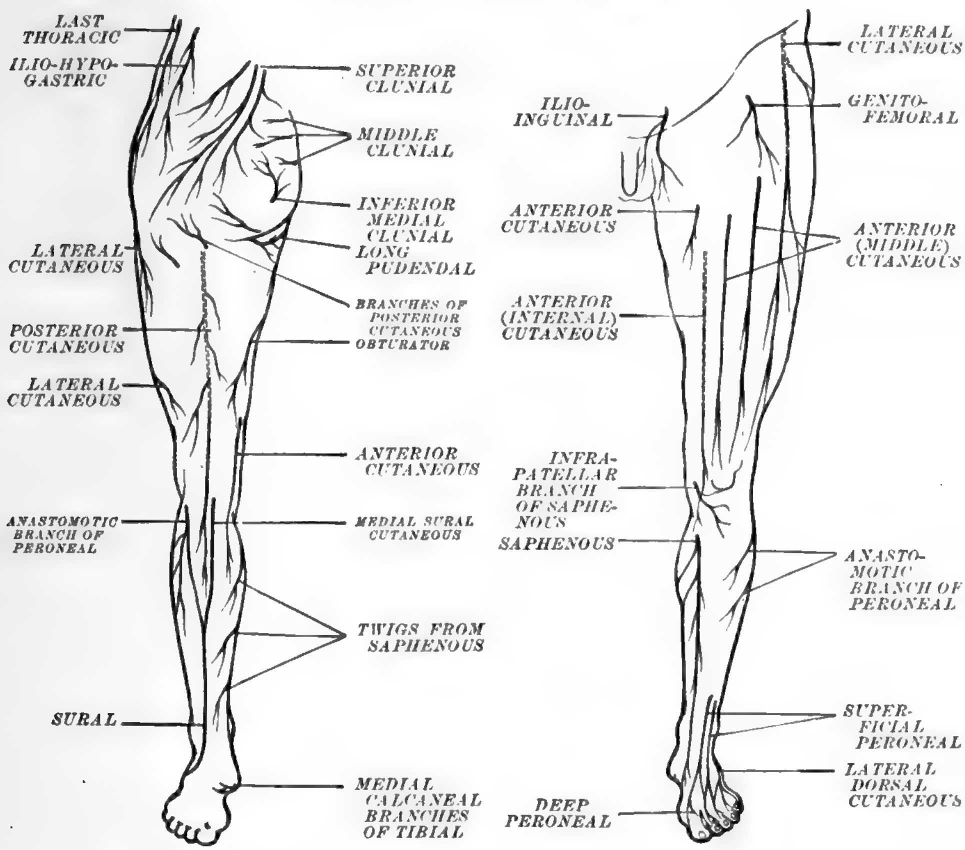
1. **Muscular branches** to the obturator externus, the oblique fibres of the adductor magnus, and to the adductor brevis when the latter is not entirely sup-

plied by the superficial branch. The branch to the obturator externus is given off in the obturator canal.

2. An **articular branch** to the knee-joint which appears in some cases to be the continuation of the trunk of the posterior branch (fig. 690). It either pierces the lower part of the adductor magnus, or it passes through the opening for the femoral artery. In the popliteal space it descends on the popliteal artery to the back of the joint, where it pierces the posterior ligament, and its terminal filaments are distributed to the crucial ligaments and the structures in their immediate neighbourhood. This branch is not uncommonly absent. Occasionally the posterior branch of the obturator nerve also supplies a twig to the hip-joint.

The **Accessory Obturator Nerve** arises from the third or fourth or from the third and fourth lumbar nerves, in the angles between the roots of the femoral (anterior crural) and obturator nerves. It is present in about ten per cent. of the cases examined. It is often closely associated with the obturator nerve to the level of the

Fig. 691.—Distribution of Cutaneous Nerves on the Posterior and Anterior Aspects of the Inferior Extremity.



brim of the pelvis, but instead of passing through the obturator foramen, it descends along the inner border of the psoas, crosses the anterior part of the brim of the pelvis, passes beneath the pectineus, and terminates in three main branches. One of these branches joins the anterior division of the obturator nerve, another supplies the pectineus, and the third is distributed to the hip-joint.

The Lumbo-sacral Trunk

The trunk usually formed by the union of the smaller part of the fourth and the entire fifth lumbar nerves is called the **lumbo-sacral trunk** (figs. 688, 693). Sometimes the larger part of the fourth nerve may help to form the trunk. It may re-

ceive fibres from the third lumbar nerve or be formed entirely from the fifth. At its formation it is situated on the ala of the sacrum under cover of the psoas. It descends into the pelvis, and, as it crosses the anterior border of the ala of the sacrum, it emerges from beneath the psoas at the inner side of the obturator nerve, from which it is separated by the ilio-lumbar artery. It passes behind the common iliac vessels and unites with the first and second sacral nerves, forming with them the upper trunk of the sacral plexus.

SACRAL NERVES

The anterior primary divisions of the upper four sacral nerves enter the pelvis through the anterior sacral foramina and they diminish in size progressively from above downwards. The first sacral is the largest of the spinal nerves, the second is slightly smaller than the first, while the third and fourth are relatively small. The fifth sacral nerve is still smaller than the fourth; it enters the pelvis between the sacrum and the coccyx. The anterior divisions of these nerves enter into the formation of three parts of the lumbo-sacral plexus, the sacral, pudendal, and coccygeal.

Sacral Plexus

The **sacral plexus** shows in its formation variations similar to those of the lumbar plexus; hence there are also seven types of this plexus, three of them belonging to the prefixed or proximal class, three to the postfixed or distal class, and one to the ordinary class. The following tables show the range of variation and the common arrangement in these classes:—

Composition of the Nerves of the Sacral Plexus

Range of Variation

Nerve.	Proximal.	Ordinary.	Distal.
Furcal	3 or 3, 4 L.	4 L.	4, 5 or 5 L.
Common peroneal (external popliteal)	3, 4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.	4, 5 L. 1, 2, 3 S.
Tibial (internal popliteal)	3, 4, 5 L. 1, 2 S.	4, 5 L. 1, 2, 3 S.	4, 5 L. 1, 2, 3 4 S.
Posterior femoral cutaneous (small sciatic)	5 L. 1, 2, 3 S.	5 L. 1, 2, 3, 4 S.	5 L. 1, 2, 3, 4 S.

Common Composition

Nerve.	Proximal.	Ordinary.	Distal.
Furcal	4 L.	4 L.	4 L.
Common peroneal (external popliteal)	4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.	4, 5 L. 1, 2 S.
Tibial (internal popliteal)	4, 5 L. 1, 2 S.	4, 5 L. 1, 2, 3 S.	4, 5 L. 1, 2, 3, 4 S.
Posterior femoral cutaneous (small sciatic)	1, 2, 3 S.	1, 2, 3 S.	2, 3 S.

The ordinary type of sacral plexus is commonly formed by the smaller part of the anterior division of the fourth lumbar nerve and the entire anterior division of the fifth lumbar nerve, together with the first and parts of the second and third sacral nerves.

The plexus lies in the pelvis on the anterior surface of the piriformis (fig. 692) and behind the pelvic fascia and the branches of the hypogastric (internal iliac) artery.

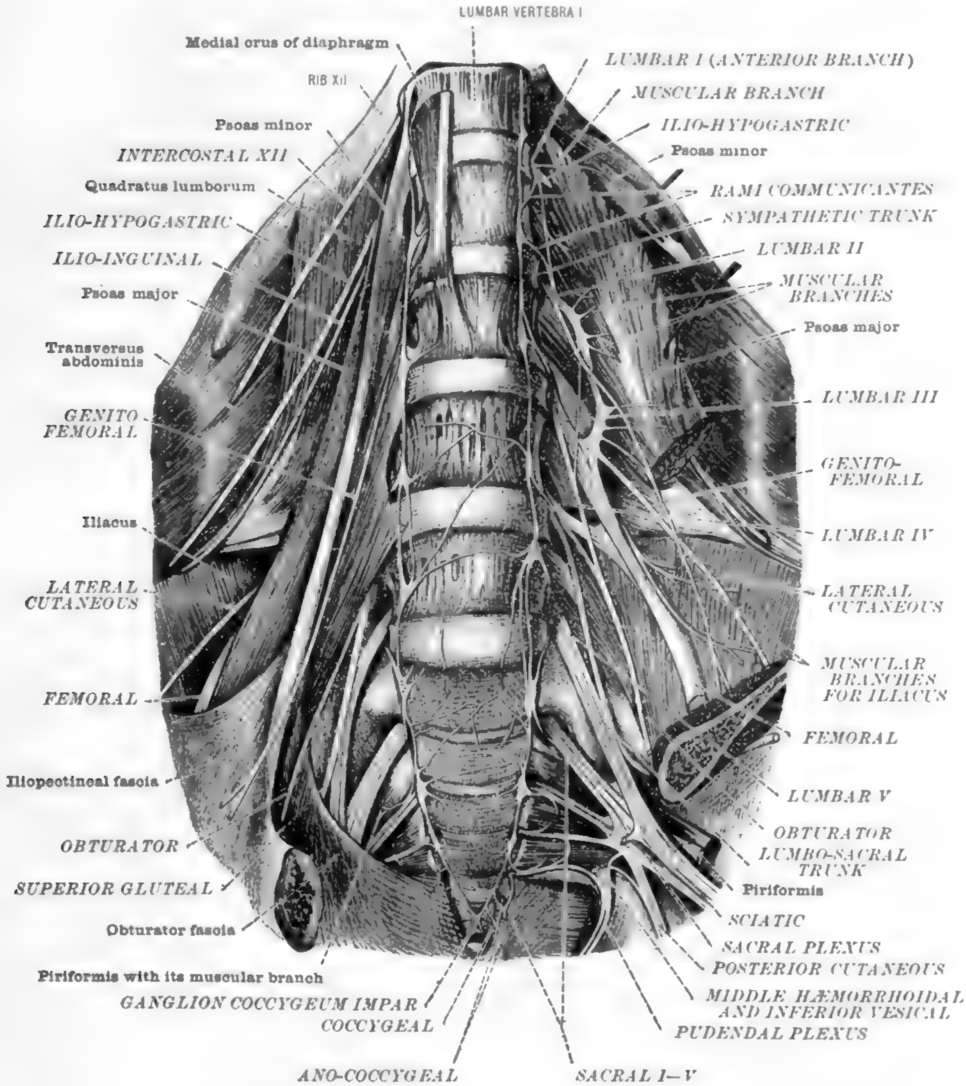
It is also behind the coils of intestine, the lower part of the ilio-pelvic colon lying in front of the left plexus, and the lower part of the ileum in front of the right plexus.

The branches given off by this plexus are:—collateral, visceral, cutaneous, and muscular.

The **collateral branches** are visceral, muscular, and cutaneous offsets.

Visceral Branches are given off from the second, third, and fourth sacral nerves to the pelvic viscera. Both the collateral and visceral branches of the plexus are relatively small and are seldom given special names.

Fig. 692.—Lumbo-sacral Plexus. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



Cutaneous branches.—(*a*) The **Posterior Femoral Cutaneous (small sciatic) nerve** arises partly from the anterior and partly from the posterior branches of the anterior primary divisions of the first, second, and third sacral nerves. It lies on the back of the plexus (figs. 692, 693), leaves the pelvis at the lower border of the piriformis, and descends in the buttock between the gluteus maximus and the posterior surface of the sciatic nerve (fig. 694). At the lower border of the gluteus maximus it passes behind the long head of the biceps femoris, and descends, immediately beneath the deep fascia, through the thigh and the upper part of the popliteal space

(fig. 691). At the lower part of the popliteal region it perforates the deep fascia, and it terminates in branches which are distributed to the skin of the calf.

Branches.—1. **Perineal branches** are distributed in part to the skin of the upper and inner sides of the thigh on its dorsal aspect. One of the branches, known as the **long pudendal nerve,** runs forwards and inwards in front of the tuberosity of the ischium to the lateral margin of the anterior part of the perineum, where it perforates the fascia lata and Colles' fascia and enters the anterior compartment of the perineum. It communicates in the perineum with the superficial perineal nerves, and its terminal filaments are distributed to the skin of the scrotum in the male, and to the labium majus in the female.

2. **Inferior clunial** (gluteal) **branches,** two or three in number, are given off beneath the gluteus maximus; they turn around the lower border of this muscle and are distributed to the skin of the lower and outer part of the gluteal region.

3. **Femoral cutaneous branches** are given off as the nerve descends through the thigh. They perforate the deep fascia and are distributed to the skin of the back of the thigh, especially on the inner side.

In case of the separate origin of the tibial (internal popliteal) and common peroneal (external popliteal) nerves, the posterior femoral cutaneous also arises from the sacral plexus in two parts. The *ventral portion* descends with the tibial nerve below the piriformis and gives off the perineal branches and inner femoral branches, while the *dorsal portion* passses through that muscle with the common peroneal nerve, and furnishes the gluteal and outer femoral branches.

(*b*) The **inferior medial clunial (perforating cutaneous) nerve** arises from the posterior portion of the second and third sacral nerves (figs. 692, 693). It perforates the lower part of the sacro-tuberous (great sciatic) ligament, turns around the inferior border of the gluteus maximus, and is distributed to the skin over the lower and inner part of that muscle. It is sometimes associated at its origin with the pudic nerve. It is not always present. Its place is sometimes taken by a small nerve (the *greater coccygeal perforating* of Eisler), arising from the third and fourth or fourth and fifth sacral nerves, and sometimes it is represented by a branch of the posterior femoral cutaneous (small sciatic).

Muscular Branches.—(*a*) One or two small **nerves to the piriformis** pass from the posterior divisions of the first and second sacral nerves.

(*b*) The **superior gluteal nerve** receives fibres from the posterior branches of the fourth and fifth lumbar, and the first sacral nerves. It passes out of the pelvis through the great sciatic foramen, above the upper border of the piriformis, and it is accompanied by the superior gluteal artery. As soon as it enters the buttock it divides into two branches, an upper and a lower.

1. The **upper branch** is the smaller. It accompanies the upper branch of the deep division of the superior gluteal artery below the middle curved line of the ilium, and it ends entirely in the gluteus medius (fig. 694).

2. The **lower branch,** larger than the upper, passes forwards across the middle of the gluteus minimus, with the lower branch of the gluteal artery; it supplies the gluteus medius and the gluteus minimus, and it ends in the inner and posterior part of the tensor fasciæ latæ.

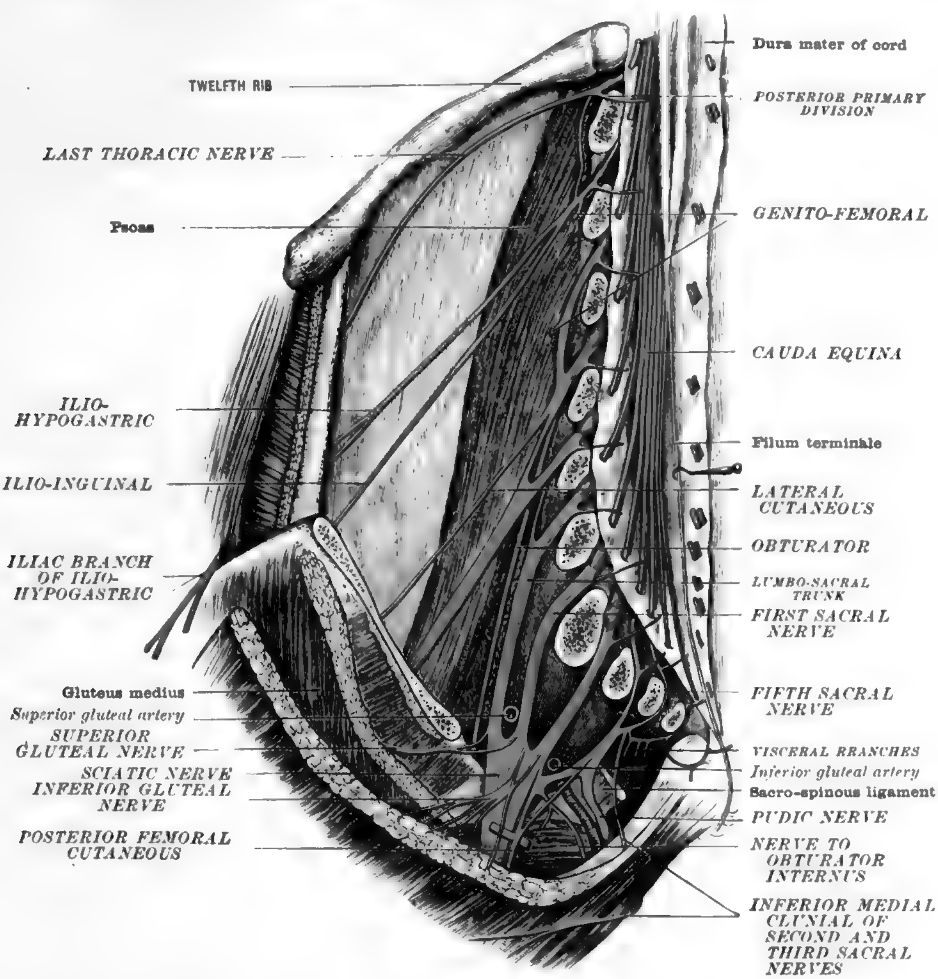
(*c*) The **inferior gluteal nerve** is formed by fibres from the posterior branches of the fifth lumbar, and the first and second sacral nerves. It passes through the great sciatic foramen, below the piriformis, and divides into a number of branches which end in the gluteus maximus (figs. 692, 693).

(*d*) The **nerve to the quadratus femoris** is formed by the anterior branches of the fourth and fifth lumbar and the first and second sacral nerves. It lies on the front of the plexus and issues from the pelvis below the piriformis. In the buttock it lies at first between the sciatic nerve and the back of the ischium, and, at a lower level, between the obturator internus with the gemelli and the ischium. It terminates in the anterior surface of the quadratus femoris, having previously given off a branch to the hip-joint and another to the inferior gemellus.

(*e*) The **nerve to the obturator internus** is formed by the anterior branches of the fifth lumbar, and the first and second thoracic nerves (figs. 692 and 693). It leaves the pelvis below the piriformis, and crosses the spine of the ischium on the outer side of the internal pudic artery and on the inner side of the sciatic nerve. It gives a branch to the gemellus superior, and turns forwards through the small sciatic foramen into the perineum, where it terminates in the inner surface of the obturator internus.

The **sciatic nerve (n. ischiadicus)**.—The sciatic is not only the largest nerve of the sacral plexus, but it is also the largest nerve in the body. Its terminal branches are chiefly muscular, though some of its fibres are cutaneous. Although it is referred to as one trunk, it consists in reality of peroneal (external) and tibial (internal popliteal) portions, which are bound together by a sheath of fibrous tissue as far as the upper end of the popliteal space. In about 10 per cent. of the cases the two parts remain separate, and in such cases the peroneal (external popliteal) part usually pierces the piriformis. The peroneal portion of the nerve consists of fibres derived from the dorsal branches of the anterior primary divisions of the fourth and fifth lumbar and the first and second sacral nerves, while the tibial part is formed

Fig. 693.—A Dissection of the Lumbar and Sacral Plexuses, from behind. (The anterior crural nerve is placed between the external cutaneous and obturator nerves.)

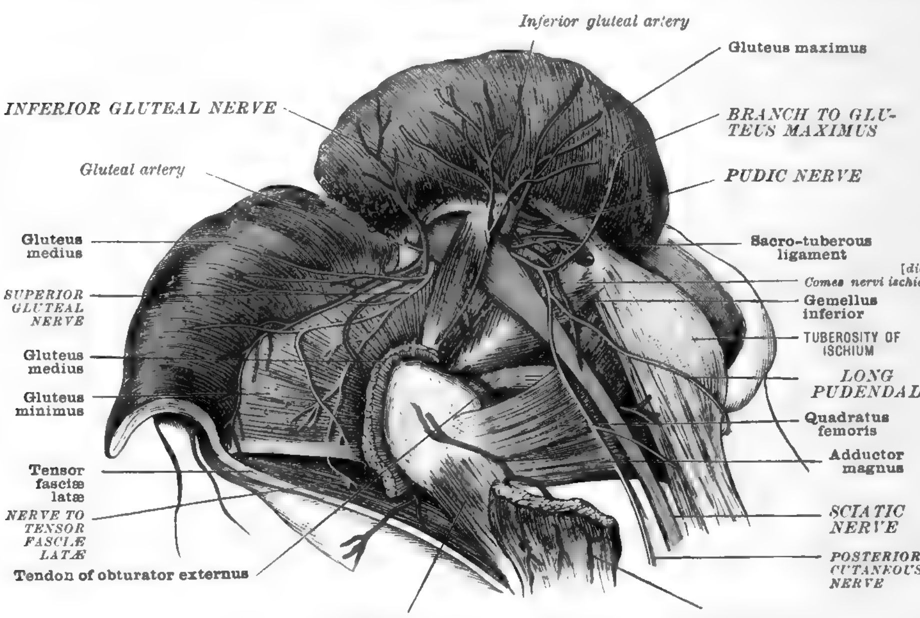


by the fibres from the anterior branches of the fourth and fifth lumbar, and the first, second, and third sacral nerves (figs. 692, 693). The common trunk leaves the pelvis by passing through the great sacro-sciatic foramen, below the piriformis, and descends through the buttock, running midway between the tuber ischii and the great trochanter (fig. 694). Passing down the thigh, it terminates at the upper angle of the popliteal space by dividing into the common peroneal (external popliteal) and the tibial (internal popliteal) nerves (fig. 695). The trunk of the nerve lies deeply in the thigh, and it is covered posteriorly by the skin and fascia, the gluteus maximus and the long head of the biceps femoris. Anteriorly it is in

relation, from above downward, with the following structures:—the posterior surface of the ischium and the nerve to the quadratus femoris, the gemellus superior, obturator internus, gemellus inferior, quadratus femoris, and adductor magnus muscles.

Muscular branches are given off at the upper part of the thigh to the semitendinosus, to the long head of the biceps femoris, to the semimembranosus, and to the adductor magnus, and, about the middle of the thigh, a branch is furnished to the short head of the biceps. The branch to the **short head of the biceps** is derived from the peroneal (external popliteal) portion of the nerve, while all the other muscular branches are given off by the tibial (internal popliteal) part. The **semitendinosus** receives two branches, one which enters it above and another which passes into it below its tendinous intersection. The nerve to the **long head of the biceps** descends along the sciatic trunk and enters the middle of the deep surface of the muscle. The nerves to the **semimembranosus** and **adductor magnus** arise by a common trunk which divides into three or four branches. One branch ends in the adductor, and the others are distributed to the semimembranosus. The branch to the adductor

Fig. 694.—A Dissection of the Nerves in the Gluteal Region.
(The gluteus maximus and gluteus medius have been divided near their insertions, and thrown upwards.)



magnus supplies only those fibres of the muscle which begin from the tuberosity of the ischium and descend vertically to the internal condyle of the femur.

At the apex of the popliteal space the two component parts of the common trunk of the sciatic become distinct. The **tibial nerve (internal popliteal),** formed by fibres from the anterior branches of the fourth and fifth lumbar and first, second, and third sacral nerves, passes vertically through the popliteal space, descends through the leg to a point midway between the internal malleolus and the most prominent part of the inner tubercle of the os calcis, where it divides into its terminal branches, the *lateral plantar* and the *medial plantar* nerves. The part of the nerve from the point of bifurcation to the lower border of the popliteus muscle is sometimes called the *internal popliteal;* the part of the nerve in the back of the leg being then designated the *posterior tibial nerve.* In the upper part of the popliteal space the tibial (internal popliteal) nerve lies relatively superficially, being covered dorsally by the skin and fascia, while in the lower part of the space it is overlapped by the heads of the gastrocnemius and is crossed by the plantaris. In the upper part of the space it lies in front of the posterior femoral cutaneous (small sciatic) nerve and to the outer

side of the vein and artery; at the middle of the space it is behind and in the lower part of the space it is internal to both of them.

The branches given off by the tibial nerve *in the popliteal space* are articular, cutaneous, and muscular.

The **articular branches** are usually three in number, a superior and an inferior internal articular and an azygos articular. They accompany the corresponding arteries, and, after piercing the ligaments, are distributed in the interior of the joint. The superior branch is often wanting.

The **cutaneous branch,** *the medial sural cutaneous* (tibial communicating) nerve, descends between the heads of the gastrocnemius, beneath the deep fascia, to the middle of the calf, where it pierces the fascia and unites with the peroneal anastomotic branch of the lateral sural cutaneous to form the sural (external saphenous) nerve, through which its fibres are distributed to the skin of the lower and back part of the leg and the outer side of the foot.

The **muscular branches** are distributed to both heads of the gastrocnemius, to the plantaris, soleus, and popliteus. The *nerve to the soleus* is relatively large, and passes between the outer head of the gastrocnemius and the plantaris before it reaches its termination (fig. 695). The *nerve to the popliteus* descends on the posterior surface of the muscle, turns around its lower border, and is distributed on its anterior aspect. In addition to supplying the popliteus, it gives articular branches to the knee and superior tibio-fibular joints, a branch to the tibia which accompanies the medullary artery, and a long, slender twig which gives filaments to the anterior and posterior tibial arteries, and it descends as the *interosseous crural nerve* (Halbertsma) on the interosseous membrane to the inferior tibio-fibular joint. It also gives branches to the interosseous membrane and to the periosteum of the lower part of the tibia.

In the upper part of the leg the tibial nerve is placed deeply, under cover of the gastrocnemius and soleus, but in the lower half it is merely covered by the deep fascia, which is thickened between the internal malleolus and the calcaneus to form the laciniate (internal annular) ligament, and the termination of the nerve lies either under cover of this ligament, or under the origin of the abductor hallucis. The anterior relations of the nerve are, from above downwards, the tibialis posterior, the flexor digitorum longus, the lower part of the tibia, and the posterior ligament of the ankle-joint. For a short distance after its commencement the nerve lies to the inner side of the posterior tibial artery; then it crosses behind the artery and runs downwards along its outer side.

The **branches** of the lower part of the tibial nerve (below the popliteal space) are likewise muscular, cutaneous, and articular. They are supplied to the deep muscles of the back of the leg, to the fibula, to the skin of the heel and foot, and to the ankle-joint. Several of the terminal branches are important enough to receive special names and special treatment.

The **muscular branches** pass from the upper part of the nerve to the tibialis posterior, flexor digitorum longus, soleus, and flexor hallucis longus. The **fibular branch** arises with the nerve to the flexor hallucis longus, and accompanies the peroneal artery. It supplies the periosteum and gives filaments which accompany the medullary artery.

The **articular branches** arise from the lower part of the nerve, immediately above its terminal branches, and they pass into the joint through the internal lateral ligament.

The **medial calcaneal (calcaneo-plantar cutaneous) nerves** arise from the trunk of the tibial nerve in the lower part of the leg. They pierce the laciniate (internal annular) ligament, and are distributed to the integument of the inner side and under surface of the heel and the adjoining part of the sole of the foot (fig. 695).

The **medial plantar nerve** is the larger of the two terminal branches of the tibial nerve. It commences under cover of the lower border of the laciniate (internal annular) ligament, or under the posterior border of the abductor hallucis, and passes forwards, accompanied by the small internal plantar artery, in the intermuscular septum between the abductor hallucis and the flexor digitorum brevis. At the middle of the length of the foot it becomes superficial, in the interval between the two muscles, and divides into four sets of terminal branches (fig. 696):—

(*a*) **Branches.—Muscular branches** pass from the trunk of the nerve to the abductor hallucis and the flexor digitorum brevis.

(*b*) **Articular branches** are distributed to the talo-navicular (astragalo-scaphoid) and the naviculari-cuneiform joint.

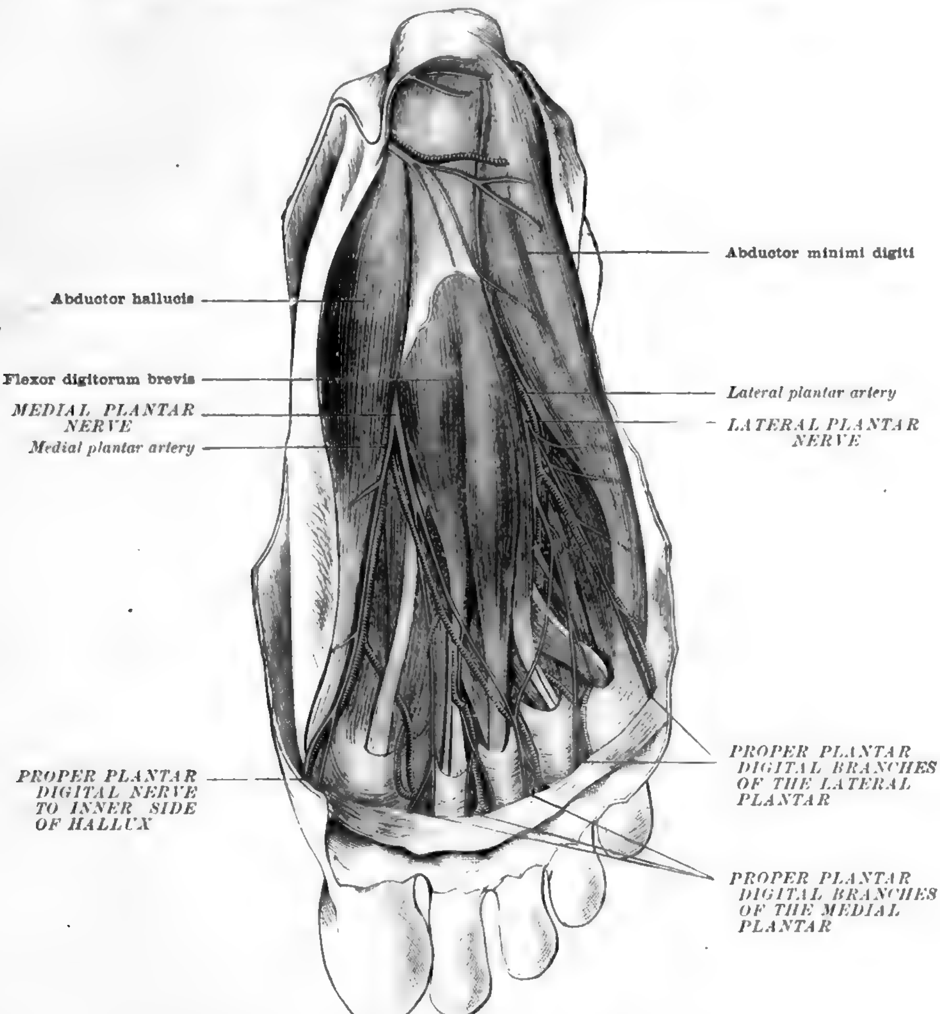
FIG. 695.—MUSCLE NERVES OF THE RIGHT LEG, VIEWED FROM BEHIND. (Spalteholz.) The semitendinosus, semimembranosus, biceps femoris, gastrocnemius, plantaris, soleus, and flexor hallucis longus have been wholly or in part removed.

(*c*) **Plantar cutaneous branches** are supplied to the skin of the inner part of the sole.

(*d*) The **digital branches** are four in number, the first, a **proper plantar digital,**

the second, third, and fourth, **common plantar digitals.** Near the bases of the metatarsal bones, the second, third, and fourth divide into **proper plantar digital nerves.** The first proper plantar digital nerve becomes subcutaneous farther back than the others, and, after sending a branch to the flexor hallucis brevis, passes to the inner side of the great toe. The second (common digital) nerve gives a twig to the first lumbrical and bifurcates to supply the adjacent sides of the first and second toes. The third supplies the adjacent sides of the second and third toes, and the fourth, after communicating with the superficial branch of the lateral plantar nerve, divides to supply the adjacent sides of the third and fourth toes. All the proper

Fig. 696.—Superficial Nerves in the Sole of the Foot. (Ellis.)



digital nerves run along the sides of the toes and lie below the corresponding arteries; they supply the joints of the toes, and each gives off a dorsal branch to the skin over the second and terminal phalanges and to the bed of the nail. All of them are connected with numerous Pacinian corpuscles.

The **Lateral Plantar Nerve** is the smaller of the two terminal branches of the tibial nerve. It commences at the lower border of the laciniate (internal annular) ligament, or under cover of the origin of the abductor hallucis, and passes forwards and outwards to the base of the fifth metatarsal bone, where it divides into a superficial and a deep branch (fig. 696). As it runs forwards and outwards it is superficial to the tendon of the flexor hallucis longus and to the quadratus plantæ (flexor

accessorius), and deep to the flexor digitorum brevis. At its termination it lies in the interval between the flexor digitorum brevis and abductor digiti quinti.

Branches.—From the trunk of the lateral plantar nerve muscular and articular branches are given off.

The **muscular branches** arise from the commencement of the nerve and are distributed to the abductor digiti quinti and quadratus plantæ.

The **articular branches** supply the calcaneo-cuboid joint.

The **superficial branch** supplies muscular filaments to the flexor digiti quinti brevis, the third plantar and fourth dorsal interosseous muscles, and divides into two **common plantar digital nerves,** each of which subdivides to form **proper plantar digital nerves.** The outer of the two branches supplies the outer side of the fifth digit; the inner communicates with the outer digital branch of the medial plantar nerve (fig. 696) and divides into proper plantar digital nerves for the adjacent sides of the fourth and fifth digits. The digital branches of the superficial division of the lateral plantar, like those of the medial plantar, supply the skin of the toes and the beds of the nails, and are associated with numerous Pacinian corpuscles.

The **deep branch** passes forwards and inwards into the deep part of the sole with the plantar arterial arch. It runs deep to the quadratus plantæ, the long flexor tendons and the lumbricals, and the oblique adductor of the great toe. It lies, therefore, immediately beneath the bases of the metatarsal bones and it supplies the following muscular and articular branches:—

Muscular branches to the outer three lumbricals, the interossei of the inner three inter-metatarsal spaces, and the transverse and oblique adductor muscles of the great toe.

Articular branches to the intertarsal and to the tarso-metatarsal joints and not uncommonly to the metatarso-phalangeal joints also. Filaments from the deep branch frequently pass through the interosseous spaces and communicate with the interosseous branches of the deep peroneal (anterior tibial) nerve.

The **Common Peroneal (External Popliteal) Nerve.**—At the apex of the popliteal space, where the two component parts of the sciatic trunk usually become distinct, the external portion receives the name *n. peronæus communis.* It descends along the posterior border of the biceps femoris, which forms the upper part of the outer boundary of the space (fig. 695). It leaves the space at the external lateral angle, crosses the plantaris, the outer head of the gastrocnemius, the popliteus, and the inferior external artery, and descends behind the upper part of the soleus, to the neck of the fibula, where it turns forwards between the peroneus longus and the bone, and breaks up into its three terminal branches, the recurrent articular, the superficial peroneal (musculo-cutaneous), and the deep peroneal (anterior tibial) nerves (fig. 697).

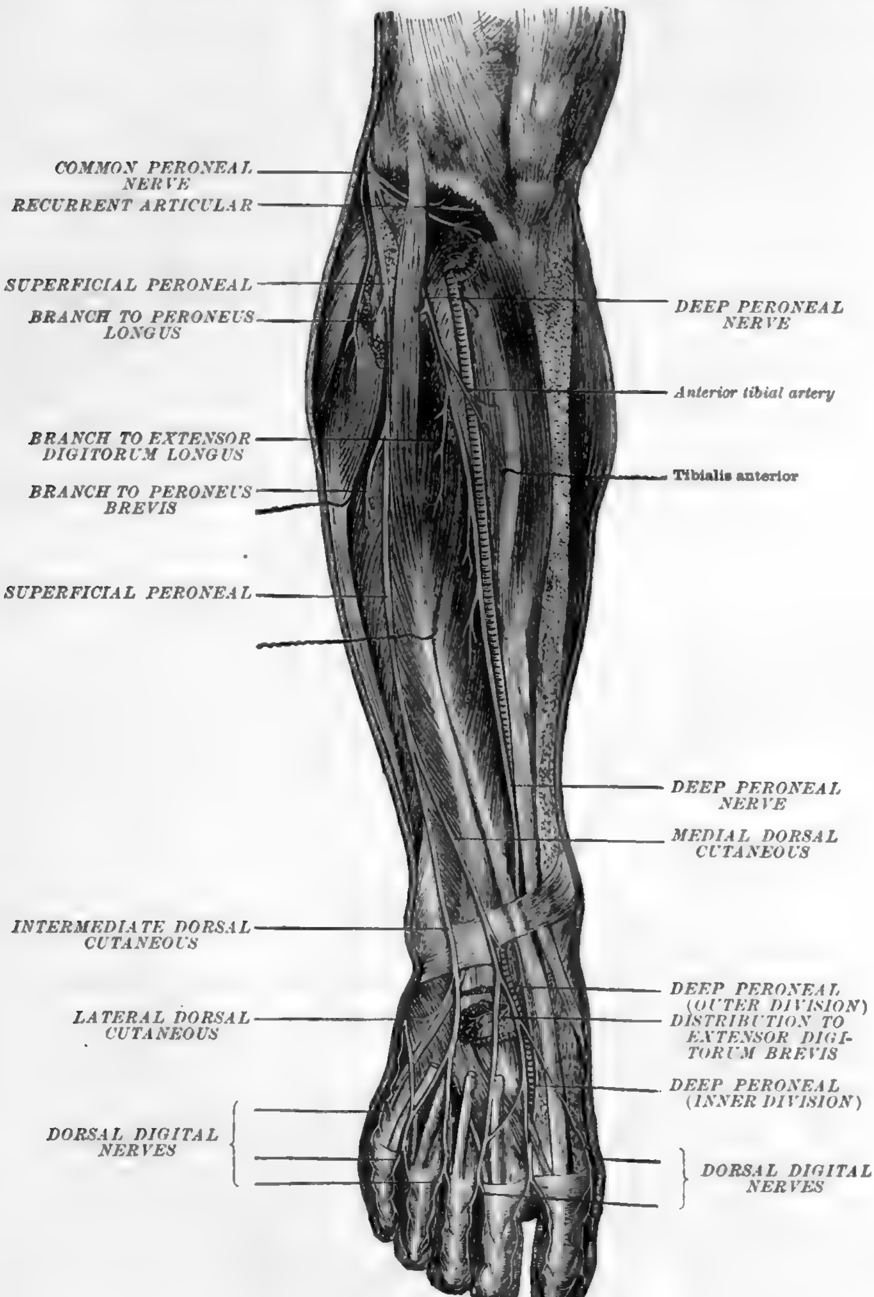
Upper branches.—While it is in the popliteal space the peroneal (external popliteal) nerve gives off two articular branches and a cutaneous branch. The **upper articular branch** accompanies the superior external articular artery. The **lower articular branch** passes down with the trunk of the nerve, across the plantaris and the outer head of the gastrocnemius, and it joins the lower external articular artery behind the tendon of the biceps femoris. Both the upper and lower articular branches pierce the ligaments and are distributed in the interior of the joint.

The **cutaneous branch** (*communicans fibularis*), *lateral sural cutaneous,* is extremely variable both as to the number of its branches and as to the place of its anastomosis with the medial sural cutaneous. Leaving the common peroneal (external popliteal) in the popliteal space, it descends between the deep fascia and the external head of the gastrocnemius to the middle of the calf, where it pierces the fascia and unites with the medial sural cutaneous to form the sural (external saphenous) nerve. In its course it may give off no branches; or it may give off several, some of which supply the skin of the back of the leg, while one of them, the peroneal anastomotic branch, unites with the medial sural cutaneous to form the sural (short saphenous) nerve. The junction of the peroneal anastomotic branch with the medial sural cutaneous may take place at any point between the popliteal space and the lower third of the leg.

The **sural (external or short saphenous) nerve** is formed by the union of the lateral sural cutaneous nerve either directly, or through a communicating branch, the peroneal anastomotic, with the medial sural cutaneous (fig. 695). It descends along the outer border of the tendo Achillis, giving branches to the lower and outer

part of the leg, and **lateral calcaneal** branches to the outer side of the heel. It passes behind the external malleolus, turns forwards across the lateral surface of the cruciate (external annular) ligament, and becomes the **lateral dorsal cutaneous nerve.** Continuing along the outer side of the foot it divides into two branches, the **dorsal**

FIG. 697.—DISTRIBUTION OF THE SUPERFICIAL AND DEEP PERONEAL NERVES ON THE ANTERIOR ASPECT OF THE LEG AND ON THE DORSUM OF THE FOOT. (Hirschfeld and Leveillé.)



digitals, one of which supplies the outer side of the fifth digit, while the other anastomoses with or takes the place of a branch of the superficial peroneal (musculocutaneous) nerve, which is distributed to the adjacent sides of the fourth and fifth digits (fig. 697).

The **recurrent articular nerve** passes inwards, around the neck of the fibula, and through the upper part of the origin of the extensor digitorum longus. At the inner border of the fibula it becomes associated with the anterior tibial recurrent artery, with which it ascends through the upper part of the tibialis anterior to the head of the tibia and the knee-joint. It supplies the tibialis anterior, the superior tibio-fibular joint, and the knee-joint.

The terminal branches.—The **superficial peroneal (musculo-cutaneous) nerve** arises from the common peroneal between the peroneus longus and the neck of the fibula and descends in the intermuscular septum between the long and short peronei on the outer side, and the extensor digitorum longus on the inner side. It gives off muscular and cutaneous branches in its descent, and at the junction of the middle and lower thirds of the leg it pierces the deep fascia and divides into an *internal* and an *external branch* (fig. 697).

Branches.—**Muscular branches** are given off to the peroneus longus and peroneus brevis before the nerve pierces the deep fascia.

Cutaneous branches pass from the trunk of the nerve to the skin of the lower part of the front of the leg.

The **internal cruciate branch,** the **medial dorsal cutaneous,** passes downwards and inwards across the upper and lower bands of the dorsal digital (anterior annular) ligament of the ankle and subdivides into two branches. The *inner branch* passes to the inner side of the great toe; it also supplies twigs to the skin of the inner side of the foot, and it anastomoses with the deep saphenous nerve and with the internal terminal branch of the deep peroneal (anterior tibial) nerve. The *outer branch* passes to the base of the cleft between the second and third toes and divides into two dorsal digital branches which supply the adjacent sides of the cleft.

The **external branch (intermediate dorsal cutaneous),** in separating from the internal branch, crosses in front of the upper and lower bands of the cruciate ligament and divides into two dorsal digital branches, which pass beneath the dorsal venous arch. The inner of these branches supplies the adjacent sides of the third and fourth toes (fig. 697). The outer branch communicates with the sural (external saphenous) nerve and is distributed to the adjacent sides of the fourth and fifth toes. This latter branch is frequently replaced by the sural nerve.

The **deep peroneal (anterior tibial) nerve** springs from the end of the common peroneal (external popliteal) nerve between the peroneus longus muscle and the neck of the fibula. It passes forwards and inwards through the upper part of the origin of the extensor digitorum longus, to the interval between that muscle and the tibialis anterior; then it descends, in the anterior compartment of the leg, to the ankle, where it divides into an inner and an outer terminal branch (fig. 697). In the upper part of the leg the nerve lies between the extensor digitorum longus and tibialis anterior and to the outer side of the anterior tibial artery. In the middle of the leg it is in front of the artery and between the extensor hallucis longus and tibialis anterior; then it crosses beneath the extensor hallucis, and in the lower third of the leg it is again to the outer side of the artery, but between the extensor hallucis longus and the extensor digitorum longus.

Branches furnished from the trunk of the nerve are muscular, articular, and terminal.

The **muscular branches** supply the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius.

Articular filaments are given to the ankle-joint and the inferior tibio-fibular articulation.

Terminal branches.—The **inner terminal branch** passes downwards along the side of the dorsalis pedis artery and divides into two dorsal digital branches which supply the adjacent sides of the first and second toes. It also gives filaments to the periosteum of the adjacent bones, to the metatarso-phalangeal and interphalangeal articulations, a twig to the dorsal interosseous muscle of the first space, and a perforating twig which communicates with the lateral plantar nerve.

The **outer terminal branch** passes outwards, beneath the extensor digitorum brevis, and it ends in a gangliform enlargement from which branches are distributed to the extensor digitorum brevis, the tarsal joints, and to the three outer intermetatarsal spaces. The latter branches supply the neighbouring bones, periosteum, and joints. They give off perforating twigs, which pass through the spaces and anastomose with branches of the lateral plantar nerve, and the innermost also gives a twig to the second dorsal interosseous muscle.

TABLE SHOWING ORDINARY RELATIONS OF LUMBAR AND SACRAL NERVES TO BRANCHES OF LUMBAR AND SACRAL PLEXUSES AND TO THE PUDIC NERVE

NERVES CONTRIBUTING.	NERVES.
1 L.	Ilio-hypogastric
	Ilio-inguinal
1 and 2 L.	Genito-femoral
1, 2, and 3 L	Lateral cutaneous
2, 3, and 4 L.	Femoral
	Obturator
4, 5 L., and 1 S.	Superior gluteal
	Nerve to quadratus femoris
4, 5 L., 1 and 2 S.	Sciatic (peroneal part)
4, 5 L., 1, 2, and 3 S.	Sciatic (tibial part)
5 L., 1 and 2 S.	Inferior gluteal
	Nerve to obturator internus
1 and 2 S.	Nerve to piriformis
2 and 3 S.	Medial inferior clunial
1, 2, and 3 S.	Posterior femoral cutaneous
2, 3, and 4 S.	Pudic

TABLE SHOWING RELATIONS OF MUSCLES OF LOWER EXTREMITY TO NERVES OF LUMBAR AND SACRAL PLEXUSES

NERVES CONTRIBUTING.	MUSCLES.	NERVES.
2 and 3 L.	Ilio-psoas	Femoral
	Sartorius	"
	Pectineus	"
	Adductor longus	Obturator
2, 3, and 4 L.	Gracilis	"
	Adductor brevis	"
3 and 4 L.	Quadriceps femoris	Femoral
	Obturator externus	Obturator
3, 4, and 5 L.	Adductor magnus	Obturator and sciatic
4, 5 L., and 1 S.	Gluteus medius	Superior gluteal
	" minimus	" "
	Tensor fasc. latæ	" "
	Semimembranosus	Sciatic
	Plantaris	Tibial
	Popliteus	"
	Quadratus femoris	Nerve to quad. fem.
	Inferior gemellus	" " "
5 L., and 1 S.	Flex. digit. long.	Tibial
	Tibialis posterior	Posterior medial
	Flexor digit. brev.	Plantar
	" hallucis brev.	"
	Abductor hallucis	"
	First lumbrical	"
5 L., 1 and 2 S.	Superior gemellus	Nerve to obt. int.
	Obturator internus	" "
	Gluteus maximus	Inferior gluteal
	Semitendinosus	Sciatic
	Soleus	Tibial
	Flex. hallucis long.	"
1 and 2 S.	Piriformis	
	Gastrocnemius	Tibial
	Flexor quadratus plantæ	Lateral plantar
	Abd. quinti digiti	" "
	Plantar interossei	" "
	Dorsal "	" "
	Add. hallucis trans.	" "
	" " obliq.	" "
1, 2, and 3 S.	Long head of biceps femoris	Sciatic

TABLE SHOWING RELATIONS OF MUSCLES OF LOWER EXTREMITY TO NERVES OF LUMBAR AND SACRAL PLEXUSES—(*Continued*)

NERVES CONTRIBUTING.	MUSCLES.	NERVES.
4, 5 L., and 1 S.........	Ext. hall. long.	Deep peroneal
	" digit. "	" "
	" digit. brev.	" "
	Tibialis anterior	" "
	Peroneus tertius	" "
	" longus	Superficial peroneal
	" brevis	" peroneal

PUDENDAL PLEXUS

The **pudendal plexus,** like the parts of the lumbo-sacral plexus already described, varies in its formation. The accompanying tables show the extreme range of variation and the common method of formation of the large nerve of this plexus in each of the three classes.

COMPOSITION OF THE NERVES OF THE PUDENDAL PLEXUS

RANGE OF VARIATION

NERVE.	PROXIMAL.	ORDINARY.	DISTAL.
Pudic nerve....................	1, 2, 3, 4, 5 S.	1, 2, 3, 4 S.	2, 3, 4, 5 S.

COMMON COMPOSITION

NERVE.	PROXIMAL.	ORDINARY.	DISTAL.
Pudic nerve....................	2, 3 S.	2, 3, 4 S.	3, 4 S.

The pudendal plexus is commonly formed by part of the anterior divisions of the second, third, and fourth sacral nerves. It lies in the lower part of the back of the pelvis, and gives off visceral, muscular, and terminal branches.

Visceral branches (pelvic splanchnics) arise from the third and fourth sacral nerves especially, and communicate with branches of the sympathetic plexus. They are distributed either directly or through this plexus to the pelvic viscera (figs. 688, 692, 693). The **middle hæmorrhoidal nerves** pass to the rectum, the **inferior vesical nerves** to the bladder, and, in the female, the **vaginal nerves** to the vagina (see SYMPATHETIC SYSTEM).

Muscular branches are given by the fourth sacral nerve to the coccygeus, levator ani, and sphincter ani externus (figs. 688, 692).

The nerves to the two former muscles pass into the pelvic surfaces of the muscles, but that to the last named muscle, called the **perineal branch,** passes backwards between the levator ani and the coccygeus, or through the posterior fibres of the latter muscle, into the posterior part of the ischio-rectal fossa, and, in addition to supplying the sphincter ani, it gives cutaneous filaments to the skin between the anus and the coccyx.

Terminal branches.—The **pudic nerve** (*n. pudendus*) rises usually from the anterior primary divisions of the second, third, and fourth sacral nerves (fig. 692). It emerges from the pelvis below the piriformis, crosses the spine of the ischium, lying to the inner side of the internal pudic artery (fig. 693), and accompanies the artery, through the small sciatic foramen, into Alcock's canal in the obturator fascia on the outer wall of the ischio-rectal fossa, where it terminates by dividing into three branches, the inferior hæmorrhoidal, the perineal, and the dorsal nerve of the penis.

The **inferior hæmorrhoidal nerves** frequently arise independently from the third and fourth sacral nerves, pierce the inner wall of Alcock's canal, and pass forwards and inwards through the ischio-rectal fat to supply the sphincter ani externus and adjacent skin. They anastomose with branches of the perineal nerve.

The **perineal nerve** runs forwards for a short distance in Alcock's canal and divides into a deep and a superficial branch. The *deep branch* breaks up into filaments, one or two of which pierce the inner wall of the canal and pass inwards to the anterior fibres of the sphincter and levator ani. The remaining part of the nerve pierces the base of the uro-genital trigone (triangular ligament), and enters the superficial pouch of the urethral triangle, where it is distributed to the bulb of the urethra,

and to the transversus perinei, bulbocavernosus, and ischiocavernosus. It also sends some filaments to supply the mucous membrane of the urethra. The *superficial branch* almost at once divides into external and internal branches, the *posterior scrotal* (*labial*) nerves. Both branches pass through the wall of Alcock's canal into the anterior part of the ischio-rectal fossa, then they pierce the base of the uro-genital trigone, and enter the superficial pouch of the urethral triangle. The external branch usually passes below the transversus perinei, and the internal branch above the muscle or through its fibres. The external branch communicates with the long pudendal nerve, and with the inferior hæmorrhoidal nerve, and both branches end in terminal filaments which anastomose and which are distributed to the skin of the scrotum and the anterior part of the perineum in the male, and to the labium majus in the female.

The **dorsal nerve of the penis** runs forwards in Alcock's canal above the internal pudic artery. It pierces the base of the uro-genital trigone, continues forwards between the layers of the trigone, embedded in the fibres of the constrictor urethræ, and it gradually passes to the outer side of the internal pudic artery. A short distance below the pudic arch it pierces the anterior layer of the uro-genital trigone, gives a branch to the corpus cavernosum penis, passes forwards between that structure and the bone, and turns downwards on the dorsum of the penis, passing between the layers of the fundiform (suspensory) ligament and along the outer side of the dorsal artery of the penis. It supplies the skin of the dorsum of the penis, and, having given branches to the prepuce, it breaks up into terminal filaments which are distributed to the glans penis.

The **dorsal nerve of the clitoris** is much smaller than the dorsal nerve of the penis to which it corresponds. It is distributed to the clitoris.

THE COCCYGEAL PLEXUS

This plexus is frequently, and with some reason, considered as a subdivision of the pudendal plexus, and sometimes it is described with the coccygeal nerves. It is formed chiefly by the anterior division of the fifth sacral nerve and the coccygeal nerve, but it receives a small filament from the anterior division of the fourth sacral nerve (figs. 688, 692, 693). These constituents unite to form plexiform cords lying on either side of the coccyx. From these cords arise the **ano-coccygeal nerves,** which pierce the sacro-tuberous (great sacro-sciatic) ligament and supply the skin in the neighbourhood of the coccyx.

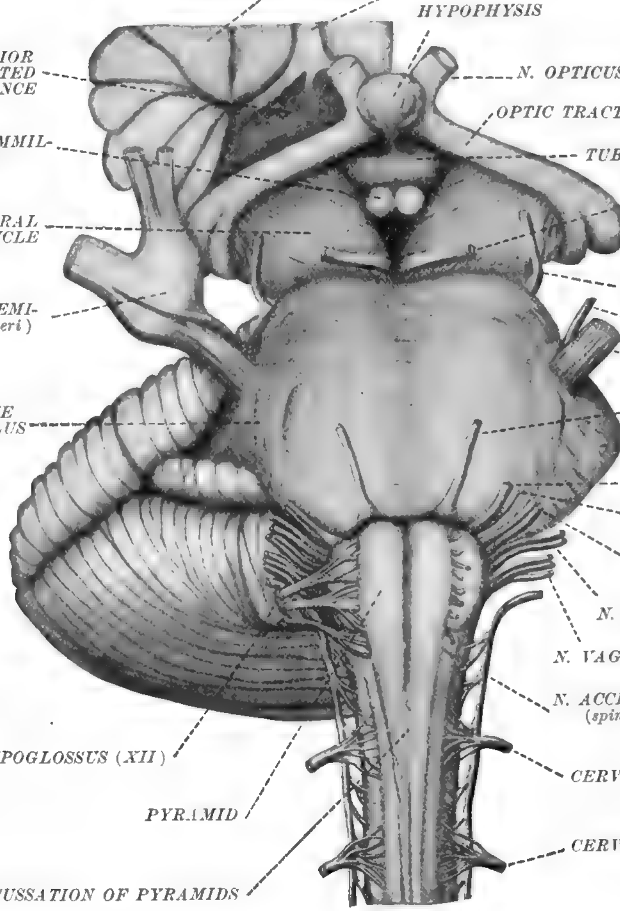
THE CRANIAL NERVES

Twelve pairs of cranial nerves are usually recognised, though there is reason for considering the nerves of the seventh and eighth pairs as composed each of two nerves, and the nerves of the eleventh pair as being merely parts of the tenth pair. The twelve are numbered from in front backwards. Their numbers, corresponding names, and functional nature are given in the following table:—

Numbers.	Names.	Nature.
I st	Olfactory	sensory
II nd	Optic	sensory
III rd	Oculomotor	motor
IV th	Trochlear or patheticus	motor
V th	Trigeminal or trifacial	mixed
VI th	Abducens	motor
VII th	Facial (Facial and Intermedius)	mixed
VIII th	Auditory (Acusticus) { Cochlearis Vestibularis }	sensory
IX th	Glosso-pharyngeal	mixed
X th	Vagus or pneumogastric	mixed
XI th	Spinal accessory	motor
XII th	Hypoglossal	motor

The cranial nerves, like the spinal nerves, are developed from cells of the primitive neural tube and, beginning with the fifth pair downwards, all the sensory nerves are developed from the cells of the neural crest like the sensory components or dorsal roots of the spinal nerves. Otherwise between the cranial nerves and the spinal nerves there are many important differences. Each spinal nerve has a dorsal or sensory root, which springs from the cells of a spinal ganglion; a ventral or motor root, whose fibres are processes of the nerve-cells which are situated in the walls of the central system, and at their attachment to the surface of the cord the two roots are some distance apart. Only two cranial nerves correspond at all closely with typical spinal nerves; they are the fifth and the seventh nerves, each of which possesses

Fig. 698.—Surface Attachment of the Cranial Nerves. (After Allen Thomson, modified).



a sensory ganglionated and a motor non-ganglionated root. But even in these cases, where the similarity between the cranial and spinal nerves is greatest, there are still points of difference, which if not essential are very obvious, for in the case of the fifth cranial nerve the motor root unites not with the whole but only with one branch of the sensory portion. In both cases the motor and sensory roots are only slightly separated from each other at their attachment to the surface of the brain. All the other cranial nerves differ in a still more marked manner from typical spinal nerves. The first nerve is an afferent nerve whose cells of origin are situated in the mucous membrane of the nose, an organ of special sense, and its fibres are not collected together into a nerve-trunk, but pass, as a number of small bundles, through the lamina

cribrosa of the ethmoid bone directly into the olfactory bulb. The second nerve is also a nerve of special sense. Its fibres form a very distinct bundle, similar in appearance to an ordinary nerve, from which, however, it differs essentially, both with regard to structure and development; for, unlike an ordinary nerve, its connective tissue consists to a large extent of neuroglia instead of ordinary connective tissue, and its component nerve-fibres are of much smaller calibre than those of an ordinary nerve. It represents the location of the original optic stalk, a diverticulum from the neural tube. The optic nerve, therefore, corresponds more closely with an association tract of the central system than with an ordinary nerve.

The third, fourth, sixth, and twelfth nerves are purely motor nerves, and thus correspond only with the ventral roots of spinal nerves. The eleventh nerve is also purely motor. Its fibres arise from the cells of the anterior horn of the spinal cord and from a nucleus of the medulla which represents a displaced portion of that horn, but they do not leave the surface of the spinal cord and brain in the usual situation of ventral roots. On the contrary, they emerge in a series of rootlets from the lateral column of the cord on the dorsal side of the ligamentum denticulatum, and from the upward prolongation of the postero-lateral sulcus.

The eighth or acoustic nerve is a nerve of special sense, and in some respects both its parts correspond closely with the dorsal root of a typical spinal nerve, and the ganglia of both its parts represent spinal ganglia, but its distribution is limited to the sense organ.

The ninth and tenth nerves contain both motor and sensory fibres, but they differ from typical spinal nerves because the motor fibres, in company with the sensory, issue from the postero-lateral sulcus of the medulla, and they are intimately intermingled, from their origin, with the sensory fibres, which latter arise from ganglia interposed in the nerves and otherwise correspond with the fibres of the dorsal root of a typical spinal nerve.

Superficial Attachments and Origins.—It is customary to speak of the area where the nerve-fibres leave or enter the brain substance as the superficial attachment of the cranial nerves, and the group of cells from which the fibres spring as their cells of origin.

THE FIRST PAIR—THE OLFACTORY NERVES

The **olfactory nerve-fibres** are the central processes of the bipolar olfactory cells situated in the olfactory region of the mucous membrane of the septal and outer walls of the nasal fossa above the level of the lower border of the superior nasal concha. As the fibres pass upwards from their cells of origin they form plexuses in the mucous membrane, and from the upper parts of these plexuses, immediately below the lamina cribrosa of the ethmoid, about twenty filaments issue on each side. These filaments comprise the **olfactory nerve.** They are non-medullated. They pass upwards, through the foramina in the lamina cribrosa, into the anterior fossa of the cranium in two rows, and after piercing the dura mater, the arachnoid, and the pia mater, they enter the lower surface of the olfactory bulb. They pass through the superficial stratum of nerve-fibres on the inferior surface of the olfactory bulb and end in the **glomeruli,** which are formed by the terminal ramifications of the olfactory nerve-fibres intermingled with the similar ramifications of the main dendrites of the large mitral cells which lie in the deeper part of the grey substance of the olfactory bulb. The olfactory nerve-fibres are grey fibres, since they do not possess medullary sheaths, and they are bound together into nerves by connective-tissue sheaths derived from the pia mater, from the subarachnoid tissue, and from the dura mater. Prolongations of the subarachnoid space pass outwards along the nerves for a short distance.

Central Connections.—The olfactory impulses are transmitted by way of the olfactory nerve-fibres through the glomeruli to the mitral cells, and they are carried to the cerebrum by the central processes (axones) of the mitral cells, which pass backwards along each olfactory tract and its three striæ olfactoriæ (see Rhinencephalon, p. 844).

THE SECOND PAIR—THE OPTIC NERVES

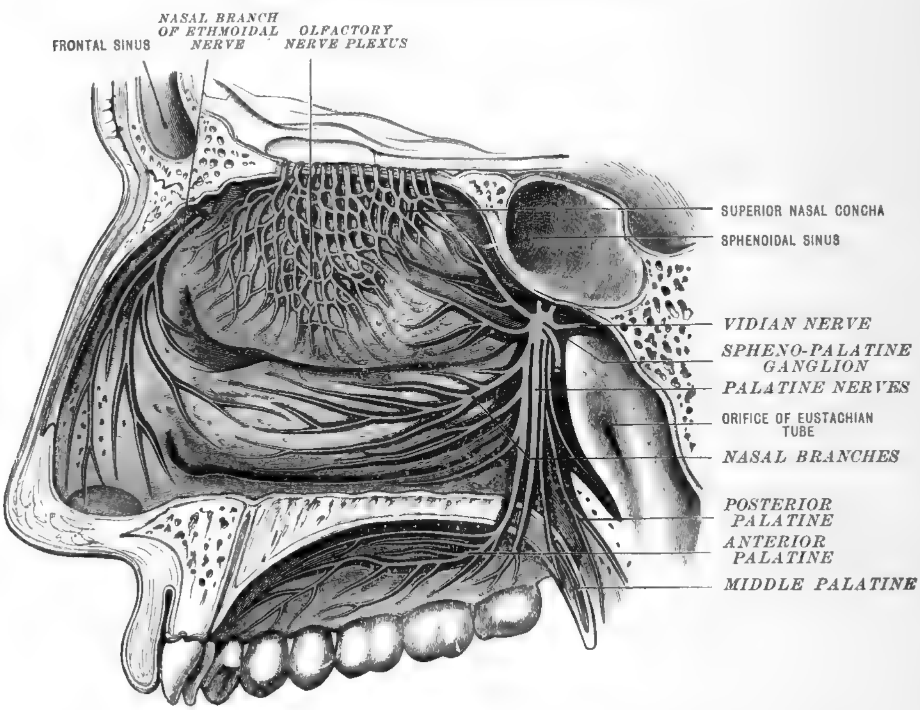
The **fibres of the optic nerve** are the central processes of the ganglion cells of the retina. Within the bulbus oculi they converge to the optic papilla, where they are

accumulated into a rounded bundle, the **optic nerve.** The nerve thus formed pierces the chorioid and the sclerotic coats, and, at the back of the bulbus, enters the orbital fat, in which it passes backwards and inwards to the optic foramen. After traversing the foramen it enters the middle fossa of the cranium, and anastomoses with its fellow from the opposite side, forming the optic chiasma. It may, therefore, for descriptive purposes, be divided into four portions—the intra-ocular, the intra-orbital, the intra-osseous, and the intra-cranial. The total length of the nerve varies from forty-five to fifty millimetres.

The **intra-ocular part** is rather less than one millimetre in length. It passes backwards from the optic papilla through the chorioid and through the sclerotic. As it passes through the latter coat of the bulbus oculi in many separate bundles, the area it traverses has a cribriform appearance when the nerve is removed, and consequently is known as the *lamina cribrosa scleræ.*

The **intra-orbital part** of the nerve emerges from the sclerotic about three millimetres below and to the median side of the posterior pole of the bulbus, and it is

Fig. 699.—Nerves of the Nasal Cavity.



about thirty millimetres long. It passes backwards and medianwards, surrounded by the posterior part of the fascia bulbi (Tenon's capsule) and by the orbital fat, to the optic foramen. As it runs backwards it is in relation above with the naso-ciliary (nasal) nerve and the ophthalmic artery which pass obliquely from behind and outside, forwards and inwards across the junction of its posterior and middle thirds, and also with the superior ophthalmic vein, the superior rectus muscle, and the upper branch of the oculo-motor nerve. Below it are the inferior rectus muscle, and the inferior division of the oculo-motor nerve. To its outer side, near the posterior part of the orbit, are the ophthalmic artery, the ciliary ganglion, the abducens nerve, and the external rectus muscle. The anterior two-thirds of this portion of the optic nerve are surrounded by the ciliary arteries and the ciliary nerves and it is penetrated on its medial and lower aspect by the central artery of the retina. As it enters the optic foramen to become continuous with the intraosseous part, it is in close relation with the ligaments of Lockwood and Zinn (annulus tendineus communis) and with the four recti muscles which arise from them.

The **intra-osseous portion** is from six to seven millimetres long. It lies be-

tween the roots of the small wing of the sphenoid and the body of that bone, and it is in relation below and laterally with the ophthalmic artery.

The **intra-cranial portion,** which is from ten to twelve millimetres long, runs backwards and medianwards, beneath the posterior part of the olfactory tract, and above the ophthalmic artery, the inner border of the internal carotid artery, and the diaphragma sellæ.

Central Connections.—The central connections of the fibres of the optic nerve have been considered with the optic chiasma and the optic tract (see p. 829).

The Sheaths of the Optic Nerve.—The optic nerve receives a sheath from each of the membranes of the brain, and prolongations of the subdural and sub-arachnoid cavities also pass outwards along it to the posterior part of the sclera (fig. 658).

THE THIRD PAIR—THE OCULO-MOTOR NERVES

The third cranial nerve or oculo-motor is a purely motor nerve. Each supplies seven muscles connected with the eye, two of which, the sphincter of the iris and ciliary muscle, are within the bulbus oculi. The remaining five are in the orbital cavity, and four of them—the superior, inferior, and internal recti and the inferior oblique—are attached to the bulbus, while the fifth, the levator palpebræ superioris, is inserted into the upper eyelid.

The fibres of each third nerve spring from their nucleus of origin situated in the grey substance of the floor of the aquæductus cerebri in the region of the superior quadrigeminate body (fig. 611). The cells of this nucleus are divided into two main groups, a superior and an inferior (fig. 612). The **superior group** includes two nuclei, a medial and a lateral. The latter, besides being lateral, is also somewhat dorsal to the former. The **inferior group** has been divided into six secondary nuclei, according to the eye-muscles the cells of each group innervate. Two of the six lie lateral to the others and somewhat dorsally, and of the remaining four, which are placed more medially, one lies in the mid-line (*nucleus medialis*) and is common to the oculo-motor nerves of both sides.

It has been found, by the study of diseased conditions and by experiments with animals, that the centres of innervation of the eye-muscles supplied by the nerve correspond to the above divisions of both the superior and inferior group of cells into a medial and lateral series. The relative position of the divisions of each group and the muscles they are thought to innervate are shown in the following diagram devised by Starr:—

Mesial Plane.

Superior Group.	Sphincter of Iris.	Ciliary Muscle.	Ciliary Muscle.	Sphincter of Iris.
Inferior Group.	Levator Palpebræ Superioris.	Internal Rectus.	Internal Rectus.	Levator Palpebræ Superioris.
	Superior Rectus.	Inferior Rectus.	Inferior Rectus.	Superior Rectus.
	Inferior Oblique.			Inferior Oblique.

As they leave the nucleus the fibres of the oculo-motor nerve form a series of fasciculi which curve ventrally through the red nucleus and the medial part of the substantia nigra, to the oculo-motor sulcus on the inner surface of the cerebral peduncle, where they emerge in from six to fifteen small bundles which pierce the pia mater and collect into the trunk of the nerve. Immediately after its formation along the oculo-motor sulcus, the trunk of the nerve passes between the posterior cerebral and the superior cerebellar arteries, and, running downwards, forwards, and laterally in the posterior part of the cisterna basalis, it crosses the anterior part of the attached border of the tentorium cerebelli at the side of the dorsum sellæ, and, piercing the arachnoid and the inner layer of the dura mater, it enters the wall of the cavernous sinus about midway between the anterior and posterior clinoid processes. Immediately after its entry into the wall of the sinus it lies at a higher level than the fourth nerve, but the latter soon crosses on its outer side and gets above it, and directly afterwards the third nerve divides into a smaller superior and a larger inferior branch (fig. 701). Before its division it receives **communications** from the cavernous plexus of the sympathetic about the internal carotid artery, and from the ophthalmic division of the fifth nerve. Both branches proceed forwards, and the nasal branch of the fifth nerve, which has passed upwards, on the outer side of the inferior branch of the third nerve, lies between them. At the anterior end of the cavernous sinus the two branches pass through the superior orbital (sphenoidal) fissure, between the heads of the external rectus muscle, and enter the orbital cavity. In the orbit, the **superior branch** lies between the superior rectus and the optic nerve; it supplies the superior rectus and then turns round the inner border of that muscle and terminates in the levator palpebræ superioris. The **inferior branch** runs forwards, beneath the optic nerve, and divides into three branches which supply the inferior and internal recti and the inferior oblique. The branch to the inferior oblique muscle is connected with the ciliary ganglion by a short thick offset, the **short root of the ciliary ganglion,** by mediation of which the oculo-motor nerve sends impulses to the ciliary muscle and the sphincter muscle of the iris. The inferior branch also gives some small twigs to the inferior rectus. The branches of the third nerve which supply the recti muscles enter the muscles on their ocular surfaces, but the branch to the inferior oblique muscle enters the posterior border of that muscle.

Some of the fibres which spring from the medial portion of the oculo-motor nucleus do not pass into the nerve of the same side, but into that of the opposite side, and it is believed that they are distributed to the opposite internal rectus muscle. Other fibres which arise from the nucleus descend in the medial longitudinal fasciculus and either terminate about the cells of the nucleus of the facial or join the facial nerve, in which they pass to the upper part of the orbicularis oculi.

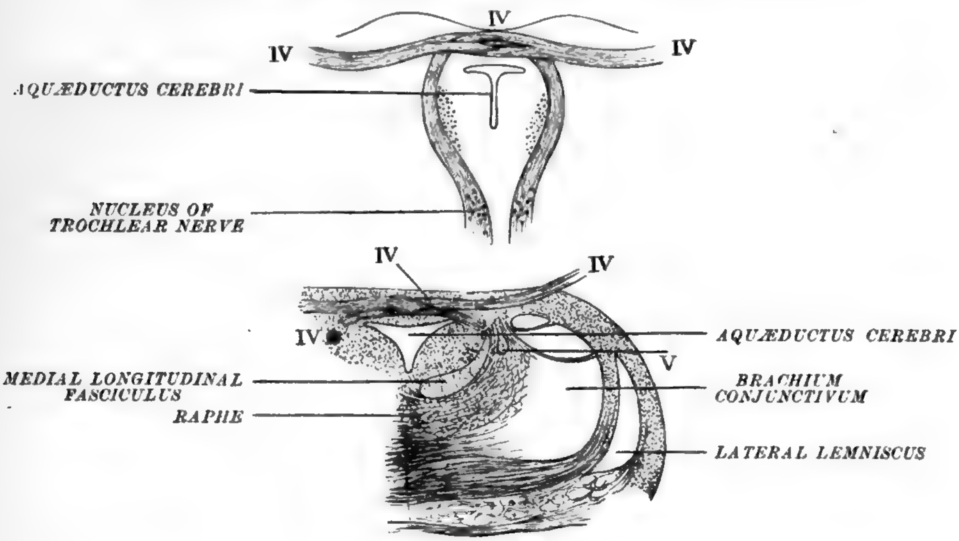
Central Connections.—The nucleus of the third nerve is associated with the anterior portion of the somæsthetic area and with the cortex about the visual area of the occipital lobe of the opposite side of the brain by the pyramidal fibres. It is probably associated with the cerebellum by the fibres of the superior cerebellar peduncles, and with the sensory nuclei of the other cranial nerves by the medial longitudinal fasciculus.

THE FOURTH PAIR—THE TROCHLEAR NERVES

The fibres of each fourth or trochlear nerve spring from the cells of a nucleus which lies in the grey substance of the floor of the aquæductus cerebri in line with the oculo-motor nucleus, but in the region of the inferior quadrigeminate bodies. As the fibres pass from their origins they run ventrally and laterally in the substance of the tegmentum for a short distance, then they curve medianwards and dorsalwards, and, in passing through the anterior end of the superior medullary velum they decussate totally with the fibres of the fourth nerve of the opposite side. After the decussation the fibres emerge from the surface of the superior medullary velum, at the side of the frenulum veli, usually in two small bundles, which pierce the pia mater and join together to form the slender trunk of the nerve. This trunk curves forwards and ventralwards to the base of the brain around the sides of the superior peduncle of the cerebellum and cerebral peduncle of the side opposite to that in which the nerve originates, running parallel with and between the superior cerebellar and posterior cerebral arteries. As it reaches the base of the brain behind the optic tract the nerve enters the cisterna basalis, in which it runs forwards, immediately beneath or piercing the free border of the tentorium cerebelli, to the superior border of the petrous portion of the temporal bone, where it pierces the arachnoid and the dura

mater and enters the posterior end of the outer wall of the cavernous sinus. In the wall of the cavernous sinus it forms **communications** with the cavernous plexus of the sympathetic and by a small filament with the ophthalmic division of the fifth nerve. It gradually ascends, as it passes forwards in the outer wall of the sinus, and, beyond the middle of the sinus, it crosses the outer side of the trunk of the oculo-motor nerve and gains a higher position. At the anterior end of the sinus the nerve enters the orbit above the external rectus and immediately turns inwards between the periosteum of the roof and the levator palpebræ superioris. At the inner border of the roof of the orbit it turns forwards to its termination, and enters the orbital or superior surface of the superior oblique muscle to which its fibres are distributed.

Fig. 700.—Diagrams of Sections through the Origin of the Fourth Nerve. (Stilling.) (The upper figure is an oblique section, the lower is a coronal section.)



The Central Connections of the nucleus of the trochlear nerve are similar to those of the oculo-motor save that its cells probably do not send fibres which connect with the facial nerve.

The trochlear is peculiar in that—(1) it is the smallest of the cranial nerves; (2) it is the only nerve having its superficial attachment upon the dorsal aspect of the encephalon; (3) it is the only cranial nerve whose fibres undergo a total decussation, and (4) in that it terminates in a muscle of the side of the body opposite that in which it has its origin. Gaskell has suggested that this latter condition has probably been brought about, phylogenetically, by the transference of the muscles which have carried their nerves with them.

THE FIFTH PAIR—THE TRIGEMINAL NERVES

Each fifth or trigeminus nerve is the largest of the cranial nerves with the exception of the optic, and it possesses both a sensory and a motor root. The fibres of the sensory root spring from the cells of the semilunar (Gasserian) ganglion, which corresponds with the ganglion on the dorsal root of a spinal nerve, and those of the motor root issue from the side of the pons, close by the side of the entering fibres of the sensory root.

The **semilunar (Gasserian) ganglion** is a semilunar mass which lies in Meckel's cave, a cleft in the dura mater above a depression in the inner part of the upper surface of the petrous portion of the temporal bone. The convexity of the ganglion is turned forwards, and from it three large nerves, the ophthalmic, the maxillary, and the mandibular, are given off. From the concavity, which is directed backwards, springs the sensory or afferent root of the fifth nerve. The inner end of the ganglion is in close relation with the cavernous sinus and the internal carotid artery at the foramen lacerum, and the outer end lies to the inner side of the foramen ovale. The surfaces of the ganglion are striated, due to bundles of fibres traversing them. The upper

surface is separated by the dura mater from the temporal lobe of the brain, and the lower rests upon the motor root of the fifth nerve and the outer layer of dura mater upon the petrous portion of the temporal bone.

The sensory root (portio major).—The fibres of the sensory root, as they leave the semilunar (Gasserian) ganglion, form from thirty to forty fasciculi which are bound together into a flat band, from six to seven millimetres broad, which passes backwards over the upper border of the petrous portion of the temporal bone and below the superior petrosal sinus into the posterior fossa of the cranium. In the posterior fossa it runs backwards, medianwards, and downwards, and passes into the pons through its continuation into the middle of the cerebellum. In the tegmentum of the pons region, the fibres bifurcate into ascending and descending branches which terminate about the cells of the (sensory) nucleus of termination of the trigeminus. This nucleus, large at the level of the entrance of the root, has a tapering inferior extremity which descends as low as the upper portion of the spinal cord and the fibres of the root terminating about the cells of this extremity are known as the spinal tract of the trigeminus.

The motor root (portio minor).—The fibres of the motor root of the fifth nerve spring from two nuclei, a slender upper or mesencephalic nucleus, and a clustered lower or principal nucleus. The fibres arising in the mesencephalic nucleus descend along the lateral aspect of the nucleus to the pons as the *descending* or *mesencephalic root;* here they join the fibres from the principal motor nucleus and issue with them from the side of the pons in from six to ten fasciculi. The fasciculi blend to form the motor root, which is from one and a half to two millimetres broad. At the point where it emerges from the pons the motor root is in front of and ventral to the sensory root, and it is separated from the latter by a few of the transverse fibres of the pons which constitute the *lingula of Wrisberg.* From its superficial attachment the motor root passes upwards, lateralwards, and forwards in the posterior fossa of the cranium, and along the inner and anterior aspect of the sensory root, to the mouth of Meckel's cave. In this cavity it runs lateralwards below the semilunar (Gasserian) ganglion to the foramen ovale, through which it passes to join the mandibular nerve immediately below the base of the skull.

Central Connections.—The motor nuclei of the fifth nerve are connected with the lower part of the somæsthetic area of the cerebral cortex of the opposite side by the genicular bundle of pyramidal fibres, and they are associated with the sensory nuclei of other cranial nerves by the medial longitudinal fasciculus. The sensory nuclei are connected with the somæsthetic area of the cortex by the fibres of the medial lemniscus (fillet) and with the motor nuclei of other cranial nerves by the medial longitudinal fasciculus. (For detailed central connections see pages 808, 810.)

THE BRANCHES OF THE TRIGEMINUS

(1) The Ophthalmic Nerve

The ophthalmic nerve is exclusively sensory, and is the smallest of the three branches which arise from the semilunar (Gasserian) ganglion. It springs from the inner part of the front of the ganglion and passes forwards, in the outer wall of the cavernous sinus, where it lies below the fourth nerve and to the outer side of the sixth nerve and the internal carotid artery (fig. 701). A short distance behind the superior orbital (sphenoidal) fissure the nerve divides into three terminal branches—the frontal, lachrymal, and naso-ciliary (nasal) nerves. They pierce the dura mater, which closes the fissure, and pass forwards into the orbit. Before its division the ophthalmic nerve receives **communicating filaments** from the cavernous plexus of the sympathetic and it gives off, soon after its origin, a **tentorial (recurrent meningeal) branch** which runs backwards, in close association with the fourth nerve, and ramifies between the layers of the tentorium cerebelli. Further forwards three **communicating branches** spring from the ophthalmic nerve and connect it with the third, fourth, and sixth nerves.

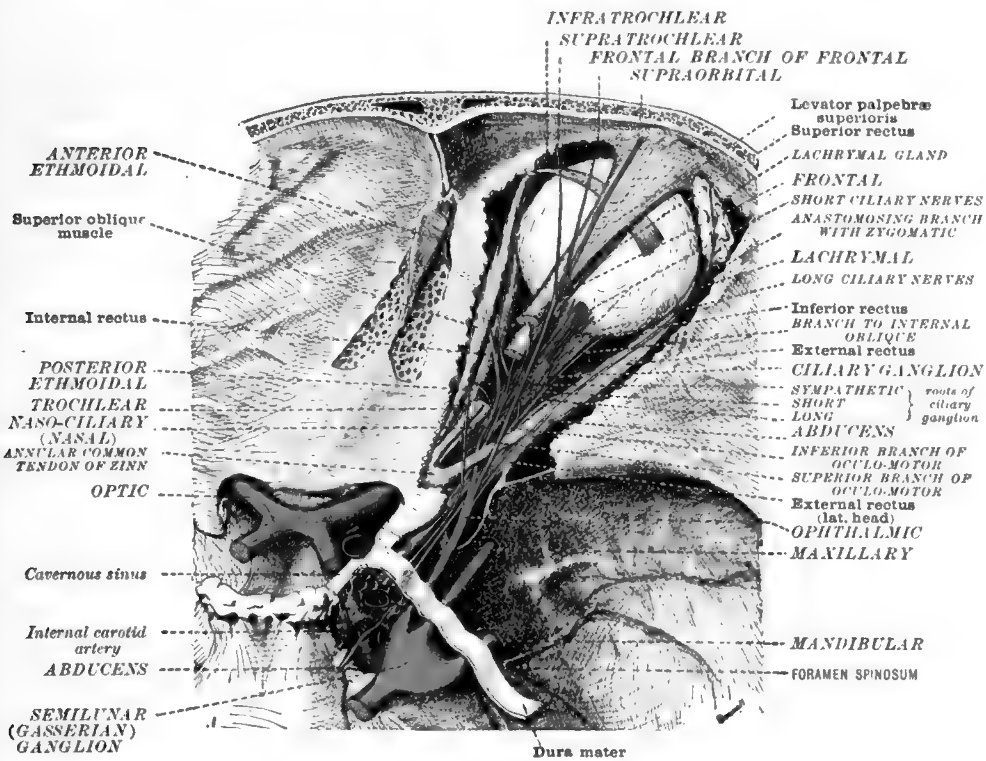
The Terminal Branches.—(*a*) The **Frontal Nerve** is the largest terminal branch. It pierces the dura mater and passes into the orbit through the superior orbital (sphenoidal) fissure, above the rectus lateralis and a little below and to the outer side of the fourth nerve. In the orbit it runs forwards, between the levator palpebræ superioris and the periosteum, and breaks up into three branches, the supra-orbital, frontal proper, and supratrochlear.

The **supra-orbital nerve,** the largest of the three branches, leaves the orbit at the supra-orbital notch (fig. 701). As it passes through the notch it gives off a small branch which enters the bone and supplies the diploë and the mucous membrane of the frontal sinus. Its terminal branches give twigs to the pericranium and to the skin of the scalp, the upper eyelid, the frontal region, and the parietal region almost as far as the lambdoid suture (fig. 705). One branch running at the upper margin of the orbital cavity unites with a branch of the facial nerve.

The **frontal branch,** given off at a variable point, lies internal to the supra-orbital, passes through the frontal foramen, and is distributed to the skin of the forehead and upper eyelid (fig. 701).

The **supratrochlear branch** runs forwards and inwards towards the upper and inner angle of the orbit, where it passes above the pulley of the superior oblique muscle, pierces the palpebral fascia, and ascends to the lower and middle part of the forehead, accompanied by the frontal artery (fig. 701). Before it leaves the

FIG. 701.—NERVES OF THE ORBIT FROM ABOVE AND BEHIND. (Schematic.)



orbit it sends a branch downwards behind or in front of the pulley of the obliquus superior to communicate with the infratrochlear nerve, and as it leaves the orbit it gives off filaments to supply the skin and conjunctiva of the inner third of the upper eyelid. Its terminal branches pierce the orbicularis and frontalis, and, as they pass to the skin of the forehead, they communicate with branches of the facial nerve.

(*b*) The **Lachrymal Nerve** is the smallest of the three branches of the ophthalmic division. It passes through the superior orbital (sphenoidal) fissure external to and slightly below the frontal nerve, and is directed forwards and outwards, along the upper border of the rectus lateralis to the lachrymal gland (fig. 701). On the lateral wall of the orbit it receives a small communicating branch from the zygomatic nerve (the orbital branch of the maxillary nerve). This communicating branch brings to the lachrymal nerve secretory fibres for the lachrymal gland. A small twig passes beyond the gland, pierces the palpebral fascia, supplies filaments to the conjunctiva, and is then distributed to the integument at the outer canthus of the eye and to the skin over the external angular process.

(*c*) The **Naso-ciliary (nasal) Nerve** enters the orbit between the two heads of the rectus lateralis and between the upper and lower divisions of the oculomotor nerve. In the orbit it lies at first on the outer side of the optic nerve, but, as it runs obliquely forwards and inwards to the inner wall of the orbital cavity, it crosses above the optic nerve and between it and the rectus superior, and near the border of the rectus medialis it divides into its two terminal branches, the infratrochlear and anterior ethmoid (fig. 701).

Its several **branches** are: (i) The **long root of the ciliary ganglion** which is given off at the superior orbital (sphenoidal) fissure. It is a slender filament which runs forwards on the outer side of the optic nerve to the upper and back part of the ganglion (fig. 701).

(ii) The **long ciliary nerves,** usually two in number, which arise from the naso-ciliary nerve as the latter is crossing above the optic nerve. They run forwards, on the inner side of the optic nerve, pierce the sclerotic, and are distributed with the lower set of short ciliary nerves (fig. 701).

(iii) The **posterior ethmoidal (spheno-ethmoidal) branch** springs from the posterior border of the naso-ciliary nerve near the upper border of the rectus medialis. It passes through the posterior ethmoidal canal and is distributed to the mucous membrane of the posterior ethmoidal cells and the sphenoidal sinus.

(iv) The **infratrochlear nerve** passes forwards between the obliquus superior and the rectus medialis, and under the pulley of the former muscle divides into two branches:—The **superior palpebral branch** helps to supply the eyelids and usually anastomoses with the supratrochlear nerve. The **inferior palpebral branch** is distributed to the lachrymal sac, the conjunctiva and skin of the inner part of the upper eyelid, the caruncle, and the skin of the upper part of the side of the nose.

(v) The **anterior ethmoidal** (distal part of the nasal) **nerve,** passing forwards and inwards between the obliquus superior and the rectus medialis, leaves the orbit through the anterior ethmoidal foramen, accompanied by the anterior ethmoidal vessels, and enters into the anterior fossa of the cranium (fig. 701). It then crosses the lamina cribrosa of the ethmoid, lying outside the dura mater, which separates it from the olfactory bulb, and descends into the nasal fossa through the ethmoidal fissure, a slit-like aperture at the side of the crista galli. In the nasal fossa it terminates by dividing into two sets of *anterior nasal branches:* the internal nasal branches and the external nasal branch (fig. 699).

The **internal nasal branches** divide into the **medial nasal branches** (the septal branches of the nasal nerve), which run downwards and forwards on the upper and front part of the septum, and the **lateral nasal branches** (the external terminal branch of the nasal nerve), which give twigs to the anterior extremities of the superior and middle nasal conchæ (turbinated bones), and to the mucous membrane of the lateral wall of the nose (fig. 699).

The **external nasal branch** (the anterior terminal branch of the nasal nerve) runs downwards in a groove on the inner surface of the nasal bone. It pierces the wall of the nose between the nasal bone and the upper lateral cartilage, and supplies the integument of the lower part of the dorsum of the nose as far as the tip.

(2) The Maxillary Nerve or Second Division of the Trigeminus

The maxillary nerve is entirely sensory in function and it is intermediate in size between the ophthalmic and mandibular nerves.

It springs from the middle of the anterior border of the semilunar (Gasserian) ganglion and runs forwards in the lower and outer part of the lateral wall of the cavernous sinus (fig. 702). Leaving the middle fossa of the cranium, by passing through the foramen rotundum, it enters the pterygo-palatine (spheno-maxillary) fossa (fig. 707), where it is connected with the spheno-palatine ganglion; then, changing its name, it passes forwards, as the **infra-orbital nerve,** through the inferior orbital (spheno-maxillary) fissure into the infra-orbital sulcus in the floor of the orbit; continuing forwards it traverses the infra-orbital canal accompanied by the infra-orbital artery, and appears in the face, beneath the quadratus (levator) labii superioris and above the caninus (levator anguli oris), where it divides into four sets of terminal branches which anastomose more or less freely with branches of the facial nerve to form the **infra-orbital plexus.**

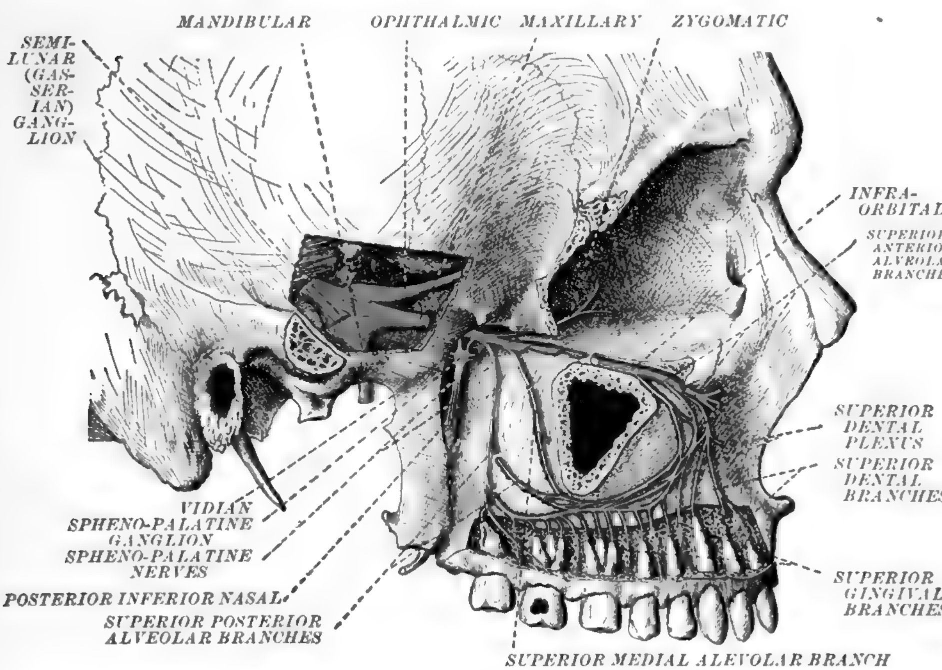
Branches.—The branches of the maxillary nerve are—(*a*) branches given off in the middle fossa of the cranium; (*b*) branches given off in the pterygo-palatine (spheno-maxillary) fossa; (*c*) branches given off in the infra-orbital sulcus and canal; and (*d*) terminal branches.

(*a*) The **middle (recurrent) meningeal branch,** given off in the middle fossa of the cranium, breaks up into numerous branches which supply the dura mater, reinforce the sympathetic plexus on the middle meningeal artery, and anastomose with the spinous nerve (the recurrent branch of the mandibular nerve).

(*b*) The branches given off in the pterygo-palatine (spheno-maxillary) fossa are the spheno-palatine nerves, the zygomatic branch, and the posterior superior alveolar nerves.

The **spheno-palatine branches,** one, two, or three branches, pass downwards in the pterygo-palatine fossa and give a small part of their fibres to the spheno-palatine (Meckel's) ganglion (fig. 702), the larger part of their fibres passing to the orbital, nasal, and palatine branches of the ganglion. (See SPHENO-PALATINE GANGLION, p. 972.)

FIG. 702.—MAXILLARY NERVE SEEN FROM WITHOUT.



The **zygomatic (orbital or temporo-malar) branch,** given off from the upper surface of the maxillary nerve, passes forwards and lateralwards, and, at the end of the inferior orbital (spheno-maxillary) fissure, passes through it into the orbit and divides into two branches, facial and temporal.

The **zygomatico-facial (malar) branch** runs forwards, passes through a zygomatico-orbital foramen, then through the zygomatico-facial (malar) foramen, pierces the orbicularis oculi, communicates with the zygomatic (malar) branch of the seventh nerve, and supplies the skin of the prominence of the cheek. The **zygomatico-temporal (temporal) branch** runs upwards in a groove in the outer wall of the orbit, passes through a zygomatico-orbital foramen, then through the zygomatico-temporal (spheno-malar) foramen, and enters the temporal fossa. It turns around the anterior border of the temporal muscle, pierces the deep layer of the temporal fascia, and runs backwards for a short distance in the fat between the superficial and deep lamellæ, then, turning outwards, it pierces the superficial lamellæ about an inch above the zygoma, anastomoses with the temporal branch of the facial nerve, and supplies the skin of the anterior part of the temporal region.

Three sets of **superior alveolar nerves** arise from the maxillary and the infra-

orbital nerves, namely, the posterior superior alveolar branches, the middle superior alveolar branch, and the anterior superior alveolar branches.

The **posterior superior alveolar (dental) nerves** are usually two in number, but sometimes arise by a single trunk. They pass downwards and outwards through the pterygo-maxillary fissure into the zygomatic fossa, where they give branches to the mucous membrane of the gums and the posterior part of the mouth; then they enter the posterior alveolar (dental) canals and unite with the other alveolar branches to form the **superior dental plexus,** through which they give branches to the roots of the molar teeth and to the mucous membrane of the maxillary sinus (fig. 702).

(*c*) The branches given off in the infra-orbital sulcus and canal are the middle and anterior superior alveolar (dental) nerves.

The **middle superior alveolar (dental) nerve** leaves the infra-orbital nerve in the posterior part of the infra-orbital sulcus, and, passing downwards and forwards in a canal in the maxilla, it divides into terminal branches that anastomose with the other alveolar branches to form the *superior dental plexus.* Through the plexus it supplies the bicuspid teeth and gives branches to the mucous membrane of the maxillary sinus and also to the gums (fig. 702).

The **anterior superior alveolar (dental) nerve** is the largest of the superior alveolar nerves. It is given off by the infra-orbital nerve in the anterior part of the infra-orbital canal, and passes downwards in a bony canal in the anterior wall of the maxilla. After uniting with the other alveolar nerves to form the superior dental plexus, it supplies the canines and the incisors and gives branches to the mucous membrane of the maxillary sinus and the gums (fig. 702). It also gives off a **nasal branch** which enters the nasal fossa through a small foramen, and supplies the mucous membrane of the anterior part of the inferior meatus and the adjacent part of the floor of the nose.

The **superior dental plexus** is formed in the bony alveolar canals by the three superior alveolar nerves. It is convex downwards and anastomoses across the mid-line with the corresponding plexus of the other side (fig. 702) From it arise the **superior dental branches** supplying the roots of the teeth, **superior gingival branches** supplying the gums, and also branches to the mucous membrane of the maxillary sinus and to the bone. On the plexus are two gangliform enlargements, one, called the *ganglion of Valentine,* situated at the junction of the middle and the posterior branches, and the other, called the *ganglion of Bochdalek,* at the junction of the middle and anterior branches.

The **infra-orbital nerve,** that part of the maxillary nerve lying distal to the spheno-palatine ganglion, enters the orbit through the inferior orbital (spheno-maxillary) fissure, accompanied by the infra-orbital artery, and with it passes through the infra-orbital canal (fig. 702) to the face, where it divides into four sets of terminal branches, some of which, by anastomoses with the branches of the facial nerve, form the **infra-orbital plexus.**

(*d*) The terminal branches of the maxillary nerve are the inferior palpebral, the external and internal nasal (nasal), and the superior labial.

The **inferior palpebral branches,** usually two, pass upwards and supply all the skin and conjunctiva of the lower eyelid (fig. 705).

The **external nasal branches** pass inwards under cover of the quadratus (levator) labii superioris, and supply the skin of the posterior part of the lateral aspect of the nose.

The **internal nasal branches** pass downwards and inwards under the lateral wall of the nose, and then turn upwards to supply the skin of the vestibule of the nose.

The **superior labial branches,** three or four in number, as a rule are larger than the palpebral and nasal branches. They pass downwards to supply the skin and mucous membrane of the upper lip and the neighbouring part of the cheek.

The Mandibular Nerve or Third Division of the Trigeminus

The **mandibular division** is the largest of the three divisions of the fifth nerve (figs. 703 and 705). It is formed by the union of two distinct parts, namely, the entire motor root of the fifth nerve and a large bundle of sensory fibres derived from the semilunar (Gasserian) ganglion. These two parts pass through the foramen ovale and unite immediately outside the skull to form a large trunk which almost directly after its formation divides into a small anterior and a larger posterior por-

tion. The trunk is situated between the pterygoideus externus externally and the otic ganglion and the tensor palati internally. In front of it is the posterior border of the pterygoideus internus, and behind it, the middle meningeal artery. Two branches arise from the trunk of the nerve before its division, namely, the spinous (recurrent) nerve and the nerve to the pterygoideus internus.

The **spinous (recurrent) nerve,** after receiving a filament from the otic ganglion, enters the cranium through the foramen spinosum, accompanying the middle meningeal artery, and divides into an anterior and a posterior branch. The anterior branch communicates with the meningeal branch of the maxillary division of the fifth nerve, furnishes filaments to the dura mater, and ends in the osseous substance of the great wing of the sphenoid. The posterior branch traverses the petrosquamous suture and ends in the lining membrane of the mastoid cells.

The **nerve to the internal pterygoid** passes under cover of a dense layer of fascia derived from an expansion of the ligamentum pterygo-spinosum, and enters the deep surface of the muscle. Near its commencement this nerve furnishes a motor root to the otic ganglion, and small branches to the tensor tympani and tensor palati.

The **Anterior Portion** of the mandibular nerve is smaller than the posterior and is chiefly motor; it supplies the muscles of mastication, the temporalis, masseter, and pterygoideus externus, and gives off a sensory branch, the buccinator (long buccal) nerve. The latter is accompanied, in the first part of its course, by a small strand of motor fibres which leaves it to end in the anterior part of the temporal muscle.

The **deep temporal nerves,** usually two in number, **posterior** and **anterior,** pass between the bone and the upper border of the external pterygoid muscle, and turn upwards around the infra-temporal crest of the sphenoid bone to end in the deep surface of the temporalis (fig. 703). The posterior of the two often arises in common with the masseteric nerve. The anterior is frequently associated with the buccinator (long buccal) nerve till the latter has passed between the two heads of the pterygoideus externus. There is frequently a third branch, the **medius,** which passes outwards above the pterygoideus externus, and turns upwards close to the bone to enter the deep surface of that muscle.

The **masseteric nerve,** which frequently arises in common with the posterior deep temporal nerves, passes between the bone and the pterygoideus externus, and accompanies the masseteric artery through the notch of the mandible to be distributed to the masseter (fig. 703). It is easily traced through the deeper fibres nearly to the anterior border of the masseter. As it emerges above the pterygoideus externus it gives off a twig to the temporo-mandibular articulation.

The **nerve to the external pterygoid,** after a course of about 3 mm. (an eighth of an inch), divides into twigs which enter the deep surface of the two heads of the muscle. It is usually adherent at its origin to the long buccal nerve.

The **buccinator (long buccal) nerve,** entirely sensory, passes between the two heads of the external pterygoid muscle and runs downwards and forwards under cover of or through the anterior fibres of the temporalis to the cheek (fig. 703). As it passes forwards it emerges from under cover of the anterior border of the masseter and lies on the superficial surface of the buccinator, where it communicates with the buccal branches of the seventh nerve and gives off filaments to supply the superjacent skin; finally it pierces the buccinator and supplies the mucous membrane on its inner surface as far forwards as the angle of the mouth. The fibres of the anterior deep temporal nerve are frequently associated with the buccinator until the latter has passed between the heads of the external pterygoid; then the anterior deep temporal nerve separates from the buccinator and passes upwards on the outer surface of the upper head of the external pterygoid.

The **Posterior Portion** of the mandibular nerve divides into three large branches. Two of these, the lingual and the auriculo-temporal nerves, are exclusively sensory; the third, the inferior alveolar (dental) nerve, contains a strand of motor fibres, the mylo-hyoid nerve.

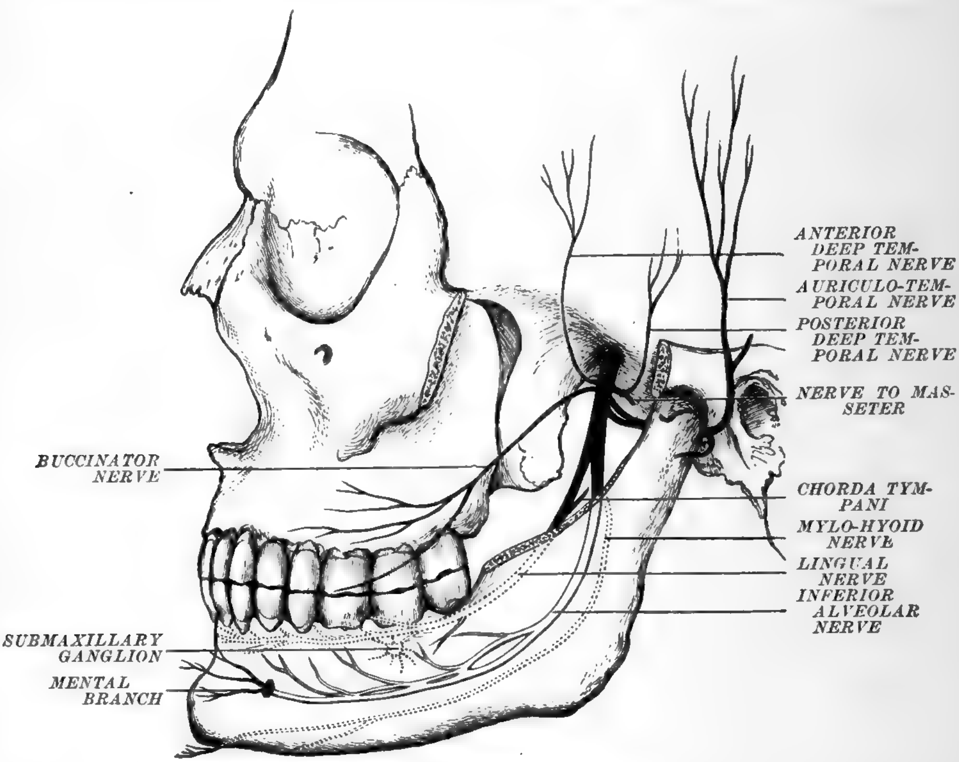
The **Lingual Nerve** is the most anterior branch of the mandibular nerve (figs. 703, 707). It lies in front and to the inner side of the inferior alveolar (dental) nerve and descends at first on the inner side of the pterygoideus externus, then between the pterygoideus internus and the ramus of the mandible to the posterior part of the mylo-hyoid ridge, where it passes off the anterior border of the pterygoideus internus; at this point it is situated a short distance behind the last molar tooth and is covered in front by the mucous membrane of the posterior part of the mouth. After leaving

the pterygoideus internus it crosses the fibres of the superior constrictor, which arise from the mandible, and turns forwards towards the tip of the tongue, crossing the outer surfaces of the stylo-glossus, hyo-glossus, and genio-glossus. In its course across the hyo-glossus it lies first above, then to the outer side of, and finally below Wharton's duct, and as it ascends on the genio-glossus it lies on the inner side of the duct.

Communications and Branches.—While it is on the inner side of the pterygoideus externus, the lingual nerve is joined, at an acute angle, by the chorda tympani (figs. 703, 707), a branch of the seventh nerve, and as it lies between the ramus of the mandible and the pterygoideus internus it is connected by a communicating branch with the inferior alveolar (dental) nerve, and gives off one or two small branches, the **rami isthmi faucium,** which pass to the tonsil and the mucous membrane of the posterior part of the mouth (fig. 707).

While it is above the duct it gives a branch, which contains many chorda tympani fibres, to the submaxillary ganglion (see p. 974), and it receives branches from

Fig. 703.—Distribution of the Mandibular Division of the Trigeminus. (Henle.)



that ganglion. A little further forwards it is connected by one or two branches, which run along the anterior border of the hyo-glossus, with the hypoglossal nerve (fig. 707). It then gives off the **sublingual nerve,** which runs forwards to supply the sublingual gland and the neighbouring mucous membrane (fig. 707). Its terminal (**lingual**) branches pierce the muscular substance of the tongue and are distributed to the mucous membrane of its anterior two-thirds. They anastomose with similar branches of the other side and with branches of the glosso-pharyngeal nerve.

The **Inferior Alveolar (dental) Nerve** is the largest branch of the posterior portion of the mandibular nerve. It commences on the inner side of the external pterygoid muscle and descends to the interval between the spheno-mandibular ligament and the ramus of the mandible, where it receives one or two communicating branches from the lingual nerve. Opposite the middle of the inner surface of the ramus it enters the mandibular (inferior dental) canal, accompanied by the inferior

alveolar (dental) artery, which lies in front of the nerve, and it runs downwards and forwards through the ramus and the body of the mandible (fig. 703). At the mental foramen it divides into two parts, one of which, the *mental nerve*, passes out through the mental foramen, the other, commonly called the *incisive branch*, continues forwards in the canal, and supplies, through the inferior dental plexus, the canine and incisor teeth and the corresponding regions of the gums.

Branches.—The branches of the inferior alveolar (dental) nerve are the mylo-hyoid, branches forming the inferior dental plexus, and the mental branch.

The **mylo-hyoid branch** is given off immediately before the inferior alveolar (dental) nerve enters the mandibular (inferior dental) canal. It pierces the lower and back part of the spheno-mandibular ligament and runs downwards and forwards in the mylo-hyoid groove between the mandible on the outer side, and the internal pterygoid muscle and the outer surface of the submaxillary gland on the inner side. In the anterior part of the digastric triangle it is continued forwards between the anterior part of the submaxillary gland and the mylo-hyoideus, and it breaks up into branches which supply the mylo-hyoideus and the anterior belly of the digastric (fig. 703).

The **inferior dental plexus** is formed by a series of branches which communicate with one another within the bone, giving rise to a fine network. From this plexus two sets of branches are given off:—the **inferior dental branches,** corresponding in number to the roots of the teeth, enter the minute foramina at the apices of the roots and end in the pulp; the second set, the **inferior gingival branches,** supply the gums.

The **mental nerve** is a nerve of considerable size which emerges through the mental foramen (fig. 703). It communicates, near its exit from the bone, with branches of the facial nerve, and then divides into three branches. The smallest branch, turning downwards, divides into several twigs, the *mental branches*, which supply the chin. The other two, *inferior labial branches*, pass upwards, diverging as they ascend, and divide into a number of twigs. The stoutest twigs ramify to the mucous membrane which lines the lower lip. Other twigs are distributed to the integument and fascia of the lip and chin.

The **Auriculo-temporal Nerve** usually arises from the posterior portion of the mandibular nerve by two roots which embrace the middle meningeal artery and unite behind it to form the trunk of the nerve. The trunk passes backwards on the inner aspect of the pterygoideus externus, and between the spheno-mandibular ligament and the temporo-mandibular articulation, lying in close relation with the capsule of the joint. Behind the joint it enters the upper part of the parotid gland, through which it turns upwards and outwards. It emerges from the upper end of the gland, crosses the root of the zygoma close to the posterior border of the superficial temporal artery, and divides into auricular and temporal terminal branches at the level of the tragus of the pinna (fig. 703).

Communications.—(*a*) Each of the two roots of the nerve receives a communication from the otic ganglion containing fibres derived from the glosso-pharyngeal nerve. These fibres have passed through the tympanic plexus and the small superficial petrosal nerve.

(*b*) Communicating filaments pass from the auriculo-temporal nerve to the temporo-facial branch of the facial nerve.

(*c*) Filaments of connection with the sympathetic plexus on the internal maxillary artery.

(*d*) A communication to the inferior alveolar (dental) nerve.

Branches.—(*a*) An **articular branch** to the temporo-mandibular joint, given off as the nerve lies on the inner side of the capsule.

(*b*) **Branches to the external auditory meatus.** Two branches, as a rule, are given off in the parotid gland. They enter the meatus by passing between the cartilage and the bone and supply the upper part of the meatus, the membrana tympani by a fine branch, and occasionally the lower branch gives twigs to the skin of the lobule.

(*c*) **Parotid branches** are distributed to the substance of the parotid gland. They spring either directly from the nerve or from the communicating branches to the facial nerve, and they contain fibres derived from the glosso-pharyngeal nerve which pass successively through its tympanic branch, the tympanic plexus, the small superficial petrosal nerve, the otic ganglion, and through the communicating twigs from the otic ganglion to the roots of the auriculo-temporal nerve.

(*d*) The **anterior auricular branches,** usually two in number, are distributed to the skin of the tragus and the upper and outer part of the pinna.

(*e*) The **superficial temporal branches** supply the integument of the greater part of the temooral region, and anastomose with the temporal branch of the seventh nerve.

THE GANGLIA CONNECTED WITH THE BRANCHES OF THE TRIGEMINUS

In addition to the semilunar (Gasserian) ganglion, which represents the ganglion of the dorsal root of a nerve of spinal type, four other ganglia are connected with the branches of the trigeminus. They are the ciliary, the spheno-palatine or Meckel's ganglion, the otic, and the submaxillary. All these ganglia correspond both structurally and developmentally with the sympathetic ganglia, and they are to be looked upon as such. They are vagrant ganglia which separated from the embryonic semilunar (Gasserian) ganglion at an early period of development and have become associated with the branches of the fifth nerve, receiving fibres which pass through them and constitute the so-called sensory roots of the ganglia. Each ganglion also receives a motor root from a cranial nerve, most of the fibres of which root terminate about its cells and each is connected with the sympathetic plexus on an adjacent artery.

THE CILIARY GANGLION

The ciliary, lenticular, or ophthalmic ganglion, lies in the posterior part of the orbital cavity, about 6 mm. in front of the superior orbital (sphenoidal) fissure, to the outer side of the optic nerve, and between the optic nerve and the external rectus muscle. It is a small, reddish, quadrangular body, compressed laterally, and it measures about two millimetres from before backwards (fig. 701).

Roots.—(*a*) Its motor or short root enters its lower and posterior angle and is derived from the branch of the lower division of the oculomotor nerve which supplies the inferior oblique muscle.

(*b*) The sensory or long root enters the upper and back part of the ganglion. It is a branch of the naso-ciliary (nasal) nerve.

(*c*) The sympathetic root consists of fibres derived from the cavernous plexus of the sympathetic; it passes to the ganglion with the long root.

Branches.—From six to eight **short ciliary nerves** emerge from the anterior border of the ganglion; they divide as they pass forwards and eventually form about twenty nerves which are arranged in an upper and a lower group, and the latter group is joined by the long ciliary branches of the naso-ciliary (nasal) nerve (fig. 701). When they reach the eyeball, the ciliary nerves pierce the sclerotic around the optic nerve, and pass forward in grooves on the inner surface of the sclera. They are distributed to the ciliary muscle, the iris, and the cornea.

THE SPHENO-PALATINE OR MECKEL'S GANGLION

This ganglion is associated with the maxillary nerve (fig. 702). It is a small reddish-grey body of triangular form, which is flattened at the sides, and measures about five millimetres from before backwards. It lies deeply in the pterygo-palatine (spheno-maxillary) fossa at the outer side of the spheno-palatine foramen and in front of the anterior end of the pterygoid (Vidian) canal. It is attached to the maxillary nerve, from which it receives its sensory root, and it is connected with the Vidian nerve, which furnishes it with motor and sympathetic filaments.

Roots.—(*a*) It is generally believed that the **motor root** is the great superficial petrosal nerve which is incorporated in the Vidian nerve. It springs from the anterior angle of the geniculate ganglion and passes through the hiatus canalis facialis (hiatus Fallopii) into the middle fossa of the cranium, where it runs forwards and inwards, in a groove on the upper surface of the petrous part of the temporal bone, to the foramen lacerum, and in this part of its course it passes beneath the semilunar (Gasserian) ganglion and the motor root of the fifth nerve. In the foramen lacerum it joins with the great deep petrosal nerve to form the Vidian nerve (nerve of the pterygoid canal), which passes forwards through the pterygoid (Vidian) canal and terminates in Meckel's ganglion in the pterygo-palatine (spheno-maxillary) fossa. The great superficial petrosal nerve contains sensory and possibly also motor fibres.

The sensory fibres ascend to the soft palate, where they are probably connected with peripheral taste organs, and they arise from the cells of the geniculate ganglion. The motor fibres, if they exist, belong either to the facial nerve or to communicating branches which have passed into it from other nerves.

(*b*) The **sympathetic root** is the great deep petrosal portion of the Vidian nerve. This root, which is of reddish colour and of soft texture, springs from the carotid plexus which lies on the outer side of the internal carotid artery in the carotid canal. It enters the foramen lacerum through the apex of the petrous portion of the temporal bone, and unites with the great superficial petrosal branch of the seventh nerve to form the Vidian nerve.

The **Vidian nerve** (**n. canalis pterygoidei**) commences by the union of the great superficial and deep petrosal nerves in the foramen lacerum, and runs forwards through the pterygoid (Vidian) canal to the pterygo-palatine (spheno-maxillary) fossa, where it terminates in Meckel's ganglion. While it is in the pterygoid canal the Vidian nerve is joined by a sphenoidal filament from the otic ganglion, and it gives branches to the upper and back part of the roof and septum of the nose, and to the lower end of the Eustachian tube.

(*c*) The **sensory root** usually consists of two spheno-palatine branches from the maxillary nerve. The majority of the fibres of these roots do not join the ganglion, but pass by its inner side and enter the palatine branches.

Branches.—The branches of the ganglion are orbital or ascending, internal or nasal, descending or palatine, and posterior or pharyngeal.

Ascending branches.—The **orbital** or **ascending branches** are two or three small twigs which enter the orbit through the inferior orbital (spheno-maxillary) fissure and proceed, within the periosteum, to the inner wall of the orbit, where they pass through the posterior ethmoidal foramen and through the foramina in the suture behind that foramen to be distributed to the mucous membrane which lines the posterior ethmoidal cells and the sphenoidal sinus.

Internal branches.—The internal or nasal branches are derived in part from the inner side of the ganglion, but are also largely made up of fibres which pass from the spheno-palatine branches of the maxillary nerve without traversing the ganglionic substance. They are disposed in two sets, the lateral and the medial (septal) posterior superior nasal branches.

The **lateral posterior superior nasal branches** are six or seven small twigs which pass through the spheno-palatine foramen, and are distributed to the mucous membrane covering the posterior parts of the superior and middle nasal conchæ (turbinated bones) (fig. 699). They also furnish twigs to the lining membrane of the posterior ethmoidal cells.

The **medial posterior superior nasal (septal) branches,** two or three in number, pass inwards through the spheno-palatine foramen. They cross the roof of the nasal fossa to reach the back part of the nasal septum, where the smaller twigs terminate. The largest nerve of the set, the **naso-palatine nerve,** or **nerve of Cotunnius,** runs downwards and forwards in a groove in the vomer between the periosteum and the mucous membrane to the incisive (anterior palatine) canal, where it communicates with the nasal branch of the anterior superior alveolar nerve. The two naso-palatine nerves then pass through the foramina of Scarpa in the intermaxillary suture, the left nerve passing through the anterior of the two foramina. In the lower part of the incisive (anterior palatine) canal the two nerves form a plexiform communication (formerly described as Cloquet's ganglion) and they furnish twigs to the anterior or premaxillary part of the hard palate behind the incisor teeth. In this situation they communicate with the anterior palatine nerves.

Descending branches.—The descending branches are the great or anterior, the posterior, and the middle (external) palatine nerves. Like the internal set of branches, they are in part derived from the ganglion and in part are directly continuous with the spheno-palatine nerves (fig. 699).

The **great** or **anterior palatine** nerve arises from the inferior angle of Meckel's ganglion, and passes downwards through the posterior palatine canal, accompanied by the descending palatine artery. Emerging from the canal at the greater (posterior) palatine foramen it divides into two or three branches, which pass forwards in grooves in the hard palate and supply the glands and mucous membrane of the hard palate and the gums on the inner aspect of the alveolar border of the upper jaw. During its course through the posterior palatine canal the anterior

palatine nerve gives off the **posterior inferior nasal nerves.** These nerves pass through small openings in the perpendicular plate of the palate bone to supply the mucous membrane covering the posterior part of the inferior nasal concha (turbinated bone) and the adjacent portions of the middle and inferior meatuses of the nose.

The **posterior** or **small palatine nerve** passes downwards through a lesser palatine foramen (accessory palatine canal), and enters the soft palate, distributing branches to that organ, to the uvula, and to the tonsil. It was formerly believed to convey motor fibres from the facial nerve to the levator palati and azygos uvulæ, but it is now believed that these muscles are supplied by the spinal accessory nerve through the pharyngeal plexus (fig. 699).

The **middle (external) palatine nerve,** the smallest of the three, traverses a lesser palatine foramen and supplies twigs to the tonsil and to the adjacent part of the soft palate (fig. 699).

Posterior branch.—The **pharyngeal branch,** which is of small size, passes backwards and somewhat inwards through the pharyngeal (pterygo-palatine) canal accompanied by a branch of the spheno-palatine artery. It is distributed to the mucous membrane of the uppermost part of the pharynx, to the upper part of the posterior nares, to the opening of the Eustachian tube, and to the lining of the sphenoidal sinus.

The Otic Ganglion

The otic or Arnold's ganglion is a small reddish-grey body which is associated with the mandibular nerve. It lies deeply in the zygomatic fossa, immediately below the foramen ovale, on the inner side of the trunk of the mandibular nerve. It is in relation internally with the tensor palati, which separates it from the Eustachian tube. In front of it is the posterior border of the pterygoideus internus, and behind it lie the middle and small meningeal arteries. It is compressed laterally, and its greatest diameter, which lies antero-posteriorly, is about three millimetres.

Roots.—The ganglion is closely connected with the nerve to the pterygoideus internus, through which it may receive a motor root from the mandibular nerve. Through the small superficial petrosal nerve, which joins the upper and back part of the ganglion, it receives a motor root from the seventh nerve and a sensory root from the ninth nerve. It receives also some root fibres from the Vidian nerve. The **sympathetic root** is derived from the sympathetic plexus on the middle meningeal artery.

Branches.—The communicating branches which pass from the ganglion are:—(1) The filaments to the chorda tympani; (2) filaments to the auriculo-temporal nerve; (3) filaments to the spinous nerve (the recurrent branch of the mandibular nerve). The branches of distribution are muscular branches to the tensor tympani, and tensor veli palatini.

The Submaxillary Ganglion

The submaxillary ganglion is suspended from the lingual division of the mandibular nerve by anterior and posterior branches. It is a small reddish body, of triangular or fusiform shape, which lies between the mylo-hyoideus and hyo-glossus and above the duct of the submaxillary gland.

Roots.—The **motor** and **sensory roots** are received from the lingual nerve. The motor fibres come from the chorda tympani after it has joined the lingual, and the sensory fibres come directly from the lingual nerve. The **sympathetic root** is formed by filaments from the sympathetic plexus on the facial artery.

Branches.—(*a*) Five or six glandular branches are given to the submaxillary gland and to Wharton's duct.

(*b*) Branches to the lingual nerve and the sublingual gland.

(*c*) To the mucous membrane of the floor of the mouth.

THE SIXTH NERVE—THE ABDUCENS

The abducens on each side arises from the cells of a nucleus which lies in the grey substance of the floor of the fourth ventricle in the region of the inferior part of the pons. The nucleus is situated close to the middle line, ventral to the striæ acusticæ and

beneath the eminentia medialis, and it is in direct linear series with the nuclei of the third, fourth, and twelfth nerves. The fibres which pass from the nucleus into the sixth nerve run inferiorly and ventralwards through the reticular formation, the trapezium, and the pyramidal fibres, and they emerge from the ventral surface of the medulla in the sulcus between the lower border of the pons and the upper end of the pyramid of the medulla. From this superficial attachment the nerve runs upwards and forwards in the subarachnoid space between the pons and the basisphenoid and at the side of the basilar artery. A little below the level of the upper border of the petrous portion of the temporal bone it pierces the dura mater, passes beneath the petro-sphenoidal ligament, at the side of the dorsum sellæ, and enters the cavernous sinus, in which it runs forwards along the outer side of the internal carotid artery. At the anterior end of the sinus it passes through the superior orbital (sphenoidal) fissure between the heads of the rectus lateralis, below the lower division of the oculo-motor nerve, and above the ophthalmic vein. In the orbit it runs forwards on the inner or ocular surface of the rectus lateralis, and finally it pierces this muscle and ends in its substance.

While it is in the cavernous sinus it receives communications from the carotid plexus of the sympathetic and from the ophthalmic nerve.

All the fibres arising in the nucleus of the sixth nerve do not pass into the sixth nerve. Some of them ascend in the medial longitudinal fasciculus, cross the mid-line, and join the third nerve of the opposite side, by which they are conveyed to the opposite internal rectus muscle. Thus impulses starting from the sixth nerve nucleus can throw into simultaneous action the external rectus of the same side and the internal rectus of the opposite side, and thus turn both eyes in the same direction.

Central Connections.—The nucleus of the sixth nerve is connected with the somæsthetic area of the opposite side by the pyramidal fibres, and it is associated with the sensory nuclei of other nerves by way of the medial longitudinal fasciculus (p. 800).

THE SEVENTH NERVE—THE FACIAL

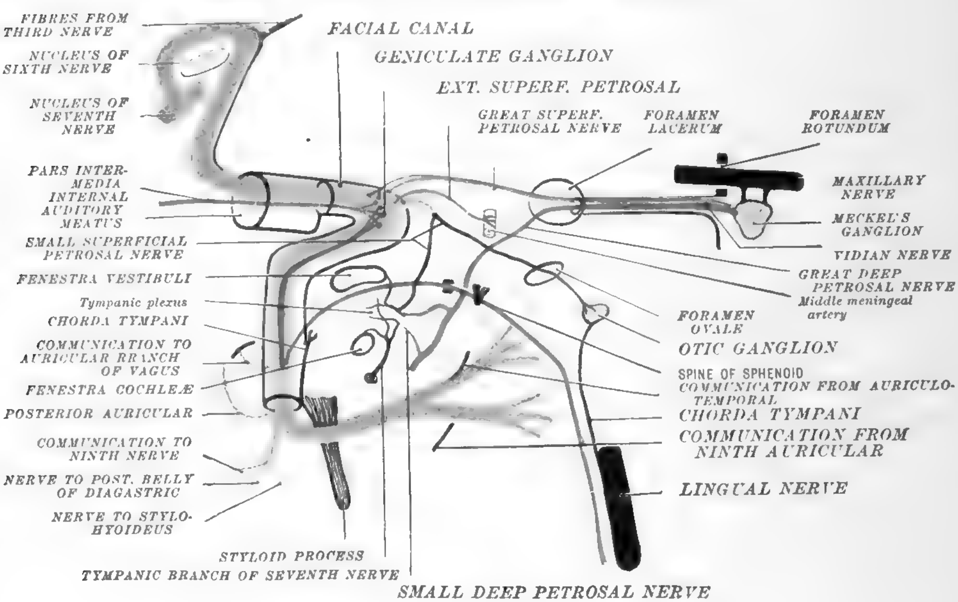
Like the trigeminus, the seventh or facial nerve is a mixed nerve. Each possesses a sensory, ganglionated and a motor, non-ganglionated root, but the double condition of the seventh is somewhat masked by the fusion of the two roots both on the inner and on the outer side of the ganglion, which is situated, therefore, on the trunk of the nerve. The ganglion is relatively small and its cells give origin, of course, to only the sensory root or pars intermedia, which is smaller than the motor root.

The Motor Root and the Trunk.—The fibres of the motor portion of the seventh nerve spring from a nucleus of cells situated laterally in the reticular formation of the lower part of the pons, dorsal to the superior olive, and between the root fibres of the sixth nerve and the laterally placed spinal tract of the trigeminus. From this nucleus the fibres of the nerve pass medially and dorsalwards to the floor of the fourth ventricle and, just under the floor, they turn anteriorly, passing dorsal to the nucleus of the abducens (fig. 603, p. 811). At the anterior end of this nucleus they turn sharply ventralwards and lateralwards, and at this point it is claimed that fibres descending in the near-by medial longitudinal fasciculus from the nucleus of the oculo-motor nerve of the same side become intermingled with the fibres of the facial nerve and pass outwards with them. Continuing ventralwards through the reticular formation the fibres of the facial emerge from the brain-stem at the inferior border of the pons, lateral to the superficial attachment of the abducens. At the point of its emergence, the facial nerve pierces the pia mater, from which it receives a sheath, and then proceeds forwards and outwards in the posterior fossa of the cranium to the internal auditory meatus, which it enters in company with its pars intermedia and with the eighth nerve. As it lies in the meatus it is situated above and in front of the eighth nerve, from which it is separated by the pars intermedia, and it is surrounded, together with the pars intermedia and the eighth nerve, by sheaths of both the arachnoid and the dura mater and by prolongations of the subarachnoid and sub-dural spaces. While it is still in the meatus it blends with the pars intermedia and thus the complete trunk of the facial nerve is formed. At the outer end of the canal the trunk pierces the arachnoid and the dura mater and enters the facial canal (aqueduct of Fallopius), in which it runs forwards and slightly outwards to the hiatus Fallopii, where it makes an angular bend, the *geniculum*, around the anterior boundary of the vestibule, and this bend is enlarged by the formation of the geniculate ganglion in its

anterior border. From the geniculum it runs dorsalwards in the facial canal along the outer wall of the vestibule and the inner wall of the tympanum, above the fenestra vestibuli (ovalis), to the junction of the inner and posterior walls of the tympanic cavity; then, bending downwards, it descends in the posterior wall to the stylo-mastoid foramen. As soon as it emerges from the stylo-mastoid foramen it turns forwards around the outer side of the base of the styloid process, and plunges into the substance of the parotid gland, where it divides into its cervico-facial and temporo-facial terminal divisions.

The Sensory Root (the pars intermedia or *nerve of Wrisberg*).—The fibres of the sensory root spring from the cells of the geniculate ganglion, which is situated in the facial canal (aqueduct of Fallopius) immediately behind the hiatus Fallopii. The central processes pass inwards in the trunk of the nerve along the facial canal to the internal auditory meatus, where they leave the trunk and form the pars intermedia, which passes inwards in the meatus and then slightly downwards in the posterior fossa of the cranium to the medulla, which it enters immediately below the lower border of the pons and between the motor root of the seventh nerve and the entering roots of the acoustic nerve. After entering the medulla the fibres pass backwards

FIG. 704.—DIAGRAM OF THE SEVENTH NERVE.



and inwards in the reticular formation, and they terminate in the upper extension of the nucleus of termination of the glossopharyngeal nerve. The sensory root or pars intermedia contains a few motor fibres probably acquired during its blending with the motor root. It is, therefore, somewhat mixed in function.

The **geniculate ganglion** is embedded in the anterior border of the geniculum of the seventh nerve behind the hiatus Fallopii. It gives origin to the greater part of the pars intermedia or sensory root of the seventh nerve. Its anterior angle is connected with the great superficial petrosal nerve, and its external angle is connected with fibres which afterwards leave the seventh nerve in its chorda tympani branch (fig. 704).

Communications and Branches.—(*a*) **In the internal auditory meatus** the pars intermedia gives two delicate filaments to the vestibular division of the auditory nerve, and it is stated that filaments are also given from the facial to the auditory artery and to the temporal bone.

(*b*) **In the facial canal** five important branches are given off, and a communication is received from the sympathetic on the middle meningeal artery.

(1) The **Great Superficial Petrosal Nerve** has been described in detail as a root of the spheno-palatine ganglion (p. 972). It arises from the geniculate ganglion of the seventh nerve, enters the middle fossa of the cranium through the hiatus Fallopii,

and passes beneath the semilunar (Gasserian) ganglion into the foramen lacerum, where it joins with the great deep petrosal nerve to form the Vidian nerve. A large part of this nerve consists of sensory fibres, but it is possible that it may also contain motor fibres.

(2) A **branch of communication** passes from the geniculum to join the small superficial petrosal nerve in the substance of the temporal bone. The fibres in this communicating branch do not appear to be connected with the cells of the geniculate ganglion (fig. 704).

(3) The **Nerve to the Stapedius** is given off from the facial as it descends in the posterior wall of the tympanum behind the pyramid.

(4) The **Chorda Tympani** consists to a very large extent of fibres which are connected with the cells of the geniculate ganglion, but it also contains some motor (probably secretory) fibres; it is, therefore, a mixed nerve. It leaves the trunk of the seventh nerve a short distance above the stylo-mastoid foramen, and pursues a slightly recurrent course upwards and forwards in the canaliculus chordæ tympani (iter chordæ posterius), a minute canal in the posterior wall of the tympanic cavity, and it enters that cavity close to the posterior border of the membrana tympani. It crosses the cavity, running on the inner surface of the tympanic membrane at the junction of its upper and middle thirds, ensheathed in mucous membrane, and passes to the inner side of the manubrium of the malleus above the tendon of the tensor tympani. It leaves the tympanic cavity and passes to the base of the skull through a small foramen (the iter chordæ anterius) at the inner end of the petro-tympanic (Glaserian) fissure. At the base of the skull it inclines downwards and forwards on the inner side of the spine of the sphenoid, which it frequently grooves, and, on the inner side of the pterygoideus externus, it joins the posterior border of the lingual nerve at an acute angle. Some of its fibres leave the lingual nerve and pass to the sub-maxillary ganglion, and others are continued forwards to the tongue. The fibres connected with the tongue are probably afferent fibres associated with the sense of taste, and they are processess of the cells of the geniculate ganglion. Before it joins the lingual nerve the chorda tympani receives a communicating twig from the otic ganglion (figs. 704, 707).

(5) Usually present is a **communicating twig to the vagus,** given off at the same level as the chorda tympani, and joining the auricular branch of the pneumogastric. While the latter twig is traversing the substance of the temporal bone, it usually receives a filament, the **external superficial petrosal,** which passes through the hiatus Fallopii and connects the geniculate ganglion with the sympathetic plexus on the middle meningeal artery.

(*c*) **After it leaves the skull** the seventh nerve gives off two or three collateral branches and two terminal divisions. The collateral branches are the posterior auricular nerve, a branch to the posterior belly of the digastric, and sometimes a lingual branch. The terminal divisions are the temporo-facial and cervico-facial.

(1) The **posterior auricular nerve** is the first branch of the extracranial portion of the facial (fig. 705). It passes between the parotid gland and the anterior border of the sterno-mastoid muscle and runs upwards in the deep interval between the external auditory meatus and the mastoid process. In this situation it communicates with the auricular branch of the vagus. It supplies the auricularis posterior, sends a slender twig upwards to the auricularis superior, and ends in a long slender branch, **the occipital branch,** which passes backwards to supply the occipitalis. It also receives filaments from the small occipital and great auricular nerves, and supplies the intrinsic muscles on the inner surface of the pinna.

(2) The **nerve to the posterior belly of the digastric** arises from the facial nerve close to the stylo-mastoid foramen and enters the muscle near its centre, or sometimes near its origin. It usually gives off two branches: the **nerve to the stylohyoid,** which sometimes arises directly from the seventh nerve and passes to the upper part of the muscle that it supplies, and the **anastomotic branch,** which joins the glosso-pharyngeal nerve below its petrous ganglion.

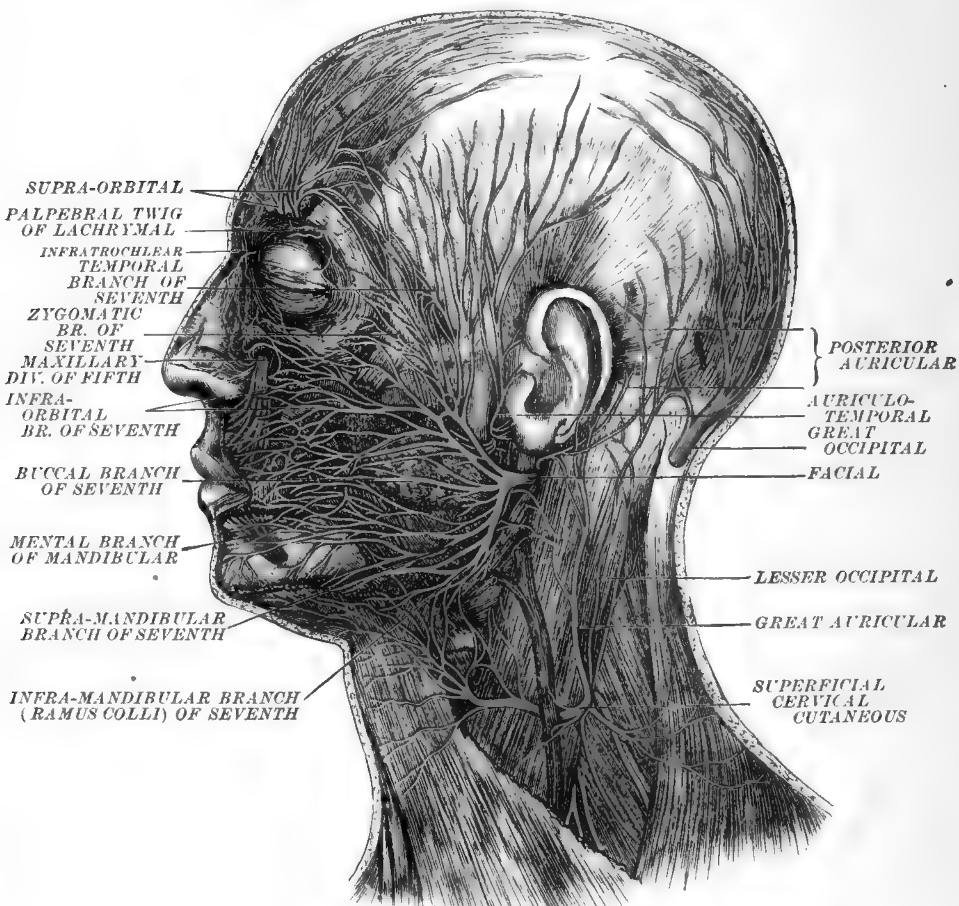
(3) The **lingual branch,** first described by Cruveilhier, is not commonly present. It arises a little below the nerve to the stylo-hyoideus and runs downwards and inwards to the base of the tongue. In its course it passes to the inner sides of the stylo-glossus and stylo-pharyngeus, and runs downwards along the anterior border of the latter muscle to the wall of the pharynx. It pierces the superior constrictor, insinuates itself between the tonsil and the anterior pillar of the fauces, and it is stated

that it gives filaments to the base of the tongue and to the stylo-glossus and glosso-palatinus (palato-glossus).

The Terminal Divisions.—In the substance of the parotid gland the two terminal divisions of the facial nerve lie superficial to the external carotid artery and to the posterior facial (temporo-maxillary) vein. The way in which these terminal divisions give off their branches varies much in different subjects and often on the opposite sides of the same subject. One of the more common methods is here described.

The **temporo-facial** or upper division runs upwards and forwards, and, after receiving communicating twigs from the auriculo-temporal nerve, gives off temporal and zygomatic (malar) branches. The **cervico-facial** or lower division runs downwards and forwards, receives branches of communication from the great auricular

Fig. 705.—Superficial Distribution of the Facial and other Nerves of the Head. (After Hirschfield and Leveillé.)



nerve, and gives off—(1) *buccal branches,* comprising what have been called infra-orbital and buccal branches; (2) the *marginal mandibular* (supra-mandibular) branch; and (3) the *ramus colli* (infra-mandibular branch). These branches from the two terminal divisions anastomose freely to form the **parotid plexus** (pes anserinus).

The **temporal branches** passing upwards communicate freely with each other and with the zygomatic branches. They also communicate with the zygomatico-temporal branch of the zygomatic nerve (the orbital branch of the maxillary nerve) and with the supra-orbital nerve. They supply the frontalis, orbicularis oculi, corrugator supercilii, and auricularis anterior and superior (fig. 705).

The **zygomatic (malar) branches** passing upwards and forwards, communicate

with the buccal branches of the seventh nerve; with the zygomatico-facial branch of the zygomatic nerve (the orbital branch of the maxillary nerve); with the supra-orbital and lachrymal branches of the ophthalmic nerve, and with the palpebral twigs of the maxillary. They supply both eyelids and the orbicularis oculi and zygomaticus (fig. 705).

The **buccal (infra-orbital and buccal) branches** arise sometimes from the lower terminal division and sometimes from both the upper and the lower terminal divisions. The buccal branches, passing forwards upon the masseter and underneath the zygomaticus and quadratus labii superioris, anastomose with the zygomatic and marginal mandibular (supra-mandibular) branches of the seventh nerve, with the buccinator (long buccal) branch of the fifth nerve, and with the terminal branches of the maxillary nerve, forming with the last-named nerve the **infra-orbital plexus.** They supply the zygomaticus, risorius, quadratus labii superioris, caninus, buccinator, incisivi, orbicularis oris, triangularis, quadratus labii inferioris, and the muscles of the nose (fig. 705).

The **marginal mandibular (supra-mandibular) branch,** passing downwards and forwards under cover of the risorius and the depressors of the lower lip, communicates with the buccal branches and with the ramus colli of the facial nerve, and with the mental branch of the mandibular nerve. It supplies the quadratus labii inferioris and mentalis.

The ramus colli (infra-mandibular branch) runs downwards and forwards under cover of the platysma, which muscle it innervates (fig. 705). Beneath the platysma it forms one or more communicating loops, near its commencement, with the great auricular nerve, and longer loops, lower down, with the superficial cervical nerve.

Central Connections.—The superior extension of the nucleus of termination of the sensory portion of the glosso-pharyngeal nerve, in which the fibres of the pars intermedia of the facial terminate, is associated with the somæsthetic area of the cortex cerebri by the medial lemniscus (fillet) of the same and opposite sides, and with the motor nuclei of the other cranial nerves by the medial longitudinal fasciculus. The motor nucleus (nucleus of origin) of the facial is associated with the somæsthetic area (lower third of the anterior central gyrus) by way of the pyramidal fasciculi of the same and opposite sides, and with the nuclei of the other cranial nerves by way of the medial longitudinal fasciculus.

THE EIGHTH NERVE—THE ACOUSTIC OR AUDITORY

Two distinct sets of fibres are contained in each acoustic nerve considered as a whole. They comprise the vestibular and cochlear divisions of the nerve, which could be well considered as separate cranial nerves. Both divisions are purely sensory in nature, that is, they are composed of afferent fibres, but, since both their peripheral distribution and their central connections are different, they must be described separately. They are distinct at their superficial attachment to the lateral aspect of the medulla oblongata at the inferior margin of the pons, the vestibular division being medial and ventral to the restiform body and just lateral to the pars intermedia of the facial, while the cochlear division is more lateral and arches around the dorsal surface of the restiform body. However, from near the medulla to the bottom of the internal acoustic (auditory) meatus the two divisions are blended into a common nerve-trunk which runs outwards, anteriorly, and upwards, in company with the facial nerve and the internal auditory artery, which course along its upper surface and are partially enclosed with it in a sheath of connective tissue. At the bottom of the internal auditory meatus the nerve is again separated into its two divisions, the vestibular above and the cochlear below.

The vestibular division or nerve.—The fibres of the vestibular division are distributed to the utriculus, the sacculus, and to the ampullæ of the three semicircular canals. None of them terminate in the cochlea, and therefore they are not considered auditory in function, but rather as having to do with the phenomena of equilibration or the sense of position of the body. In the internal auditory meatus the vestibular division is connected by small filaments with the pars intermedia of the facial nerve, both giving fibres to and probably receiving fibres from the geniculate ganglion. At the bottom of the meatus there is interposed in the vestibular division its ganglion of origin, the **vestibular ganglion** (ganglion of Scarpa). Unlike the ordinary spinal ganglion, to which it corresponds, the vestibular ganglion consists

of bipolar cells, or cells which give off their central and peripheral processes directly from opposite sides of the cell-body. The central fibres (axones) enter the medulla oblongata.

The **peripheral fibres** from the vestibular ganglion separate into an upper and a lower branch. The upper or **utriculo-ampullar branch** divides into the following terminal branches:—

(1) The **utricular branch** passes through the superior macula cribrosa of the vestibule and terminates in the macula acustica of the utriculus.

(2) Accompanying the utricular branch through the superior macula cribrosa is a branch, the **superior ampullar,** to the crista acustica of the ampulla of the superior semicircular canal, and—

(3) A similar branch, the **lateral ampullar,** to the ampulla of the lateral semicircular canal.

The lower or **sacculo-ampullar branch** accompanies the cochlear division a short distance further than the upper, and divides into—

(1) A branch, the **posterior ampullar,** which passes through the foramen singulare and the inferior macula cribrosa and terminates in the ampulla of the posterior semicircular canal, and—

(2) A branch, the **saccular,** which passes through the middle macula cribrosa and terminates in the macula acustica of the sacculus.

The central connections of the vestibular division are described in detail on pages 805, 806. Its large nucleus of termination, spread through the area acustica in the floor of the fourth ventricle, and divided into four sub-nuclei, is associated with the nuclei fastigii, globosus, and emboliformis of the cerebellum, with the nuclei of the eye-moving nerves, with the spinal cord, and probably with the cerebral cortex.

The cochlear division or nerve.—The fibres of this division are distributed to the organ of Corti in the cochlea, and so are considered as comprising the auditory nerve proper. They arise from the long, coiled **spiral ganglion** of the cochlea, the cells of which are likewise bipolar. The **peripheral fibres** of these cells (dendrites) are shorter than those of the vestibular ganglion. They terminate about the auditory or hair-cells of the organ of Corti and thus collect impulses aroused by stimuli affecting these cells. The *central fibres* of the ganglion continue the central course through the modiolar canal and the tractus spiralis foraminosus of the cochlea, and thence, joining the vestibular division through the internal auditory meatus, they enter the brain-stem to terminate in their dorsal and ventral nuclei. A description of these nuclei and the further central connections of the cochlea with the superior olive, the nuclei of the eye-moving nerves, the inferior quadrigeminate bodies, the medial geniculate bodies, and with the cerebellum and temporal lobes of the cerebral hemispheres is given on pages 806, 807.

THE NINTH NERVE—THE GLOSSO-PHARYNGEAL

The glosso-pharyngeal nerves are mixed nerves and each is attached to the medulla by several roots which enter the postero-lateral sulcus, a short distance behind the olivary body and in direct line with the facial nerve.

The filaments, when traced outwards, are seen to blend, in front of the flocculus, into a trunk which lies in front of the tenth nerve, but which passes through a separate opening into the arachnoid and the dura mater and through the jugular foramen. In the foramen this trunk lies in front and outside of the tenth nerve in a groove on the petrous portion of the temporal bone, and in this situation two ganglia are interposed in it, a superior or jugular, and an inferior or petrous. After it emerges from the jugular foramen the glosso-pharyngeal nerve descends at first between the internal carotid artery and the internal jugular vein and to the outer side of the vagus; then, bending forwards and inwards, it descends internal to the styloid process and the muscles arising from it, and turning around the lower border of the stylo-pharyngeus it passes between the internal and the external carotid arteries, crosses the superficial surface of the stylo-pharyngeus, and runs forwards and upwards, internal to the hyoglossus muscle and across the middle constrictor and the stylo-hyoid ligament, to the base of the tongue (fig. 707).

Ganglia.—The **superior or jugular ganglion** or ganglion of Ehrenritter, is a small, ovoid, reddish-grey body which lies on the back part of the nerve-trunk in the

upper part of the jugular foramen. No branches arise from it. It is sometimes continuous with the petrous ganglion or it may be absent.

The **inferior or petrous ganglion,** or ganglion of Andersch, is an ovoid grey body which lies in the lower part of the jugular foramen, and appears to include all the fibres of the nerve.

Communications.—(1) The petrous ganglion is connected with the superior cervical ganglion of the sympathetic by a fine filament.

(2) It also has a filament of communication with the auricular branch of the vagus which varies inversely in size with the latter nerve and sometimes entirely replaces it. This filament may be absent.

(3) An inconstant communication with the ganglion of the root of the vagus.

(4) A short distance below the petrous ganglion the trunk of the nerve is connected by a twig with that branch of the seventh nerve which supplies the posterior belly of the digastric muscle.

Branches.—(*a*) **From the petrous ganglion:** The **tympanic branch, or nerve of Jacobson,** arises from the petrous ganglion and passes through a foramen, which lies in the ridge of bone between the carotid canal and the jugular fossa, into the tympanic canaliculus (Jacobson's canal), where it is surrounded by a small, fusiform mass of vascular tissue, the *intumescentia tympanica.* After traversing the tympanic canaliculus it enters the tympanum at the junction of its lower and inner walls, and, ascending on the inner wall, breaks up into a number of branches which take part in the formation of the **tympanic plexus** on the surface of the promontory. The continuation of the nerve emerges from this plexus as the *small superficial petrosal nerve,* which runs through a small canal in the petrous portion of the temporal bone, beneath the canal for the tensor tympani, and appears in the middle fossa of the cranium through a foramen which lies in front of the hiatus Fallopii. From this foramen it runs forwards and passes through the foramen ovale, the canaliculus innominatus, or the spheno-petrosal suture, and enters the zygomatic fossa, where it joins the otic ganglion. While it is in the canal in the temporal bone the small superficial petrosal nerve is joined by a branch from the geniculate ganglion of the facial nerve.

(*b*) **Branches from the plexus:**—(1) The **tubal branch,** a delicate branch, which runs forwards to the mucous membrane of the tuba auditiva (Eustachian tube) and sends filaments backwards to the region of the fenestra vestibuli (ovalis) and the fenestra cochleæ (rotunda).

(2) The **superior and inferior carotico-tympanic (carotid) branches** pass medianwards to the internal carotid plexus.

(*c*) **From the trunk of the nerve:**—(1) **Pharyngeal branches,** which may be two or three in number, arise from the nerve a short distance below the petrous ganglion. The principal and most constant of these passes on the outer side of the internal carotid artery, and after a very short independent course joins with the pharyngeal branch of the vagus and with branches of the superior cervical ganglion to form the pharyngeal plexus (fig. 707).

(2) A **muscular branch** is distributed to the stylo-pharyngeus muscle. This branch receives a communication from the facial nerve (fig. 707).

(3) The **tonsillar branches** are a number of small twigs which arise under cover of the hyo-glossus muscle; they proceed to the tonsil, around which they form a plexus, the **circulus tonsillaris.** From this plexus fine twigs proceed to the pillars of the fauces and to the soft palate.

(4) The **lingual branches** arise from the termination of the nerve and supply the mucous membrane of the posterior half of the dorsum of the tongue, where, chiefly as taste-fibres, they are distributed to the vallate papillæ. Some small twigs pass backwards to the follicular glands of the tongue, and to the anterior surface of the epiglottis. Other twigs are distributed around the foramen cæcum, where they communicate with the corresponding twigs of the opposite side.

The Sensory Fibres.—The sensory fibres of the ninth nerve spring from the superior and petrous ganglia and pass peripherally and centrally. The **peripheral fibres** of the ganglion cells are those which are distributed to the mucous membrane of the tongue and pharynx, and the **central fibres** pass inwards to the medulla. In the medulla they pass dorsalwards and medianwards through the reticular formation and, bifurcating into ascending and descending branches, they end in the nucleus of termination of the ninth nerve, that is, in the upper part of the nucleus alæ cinereæ and in the nucleus of the tractus solitarius.

The **Motor Fibres** arise from the nucleus ambiguus in the lateral column of the medulla, in line with the motor nucleus of the facial nerve. From this nucleus they pass at first dorsalwards and then, turning lateralwards, they emerge and join the sensory fibres and run with them in the trunk of the nerve (fig. 598).

Van Gehuchten's observations point to the conclusion that one motor nucleus of the ninth nerve is separate from and lies above and to the medial side of the nucleus ambiguus, and that a portion of the nucleus of the ala cinerea is also a motor nucleus common to the ninth and tenth nerves.

Central Connections.—The nuclei of termination of the ninth nerve are connected with the motor nuclei of other cranial nerves by the medial longitudinal fasciculus, and with the somæsthetic area of the cortex cerebri by the medial lemniscus (fillet). The motor nucleus of the ninth nerve is associated with the somæsthetic area by the pyramidal fibres.

THE TENTH NERVE—THE VAGUS OR PNEUMOGASTRIC

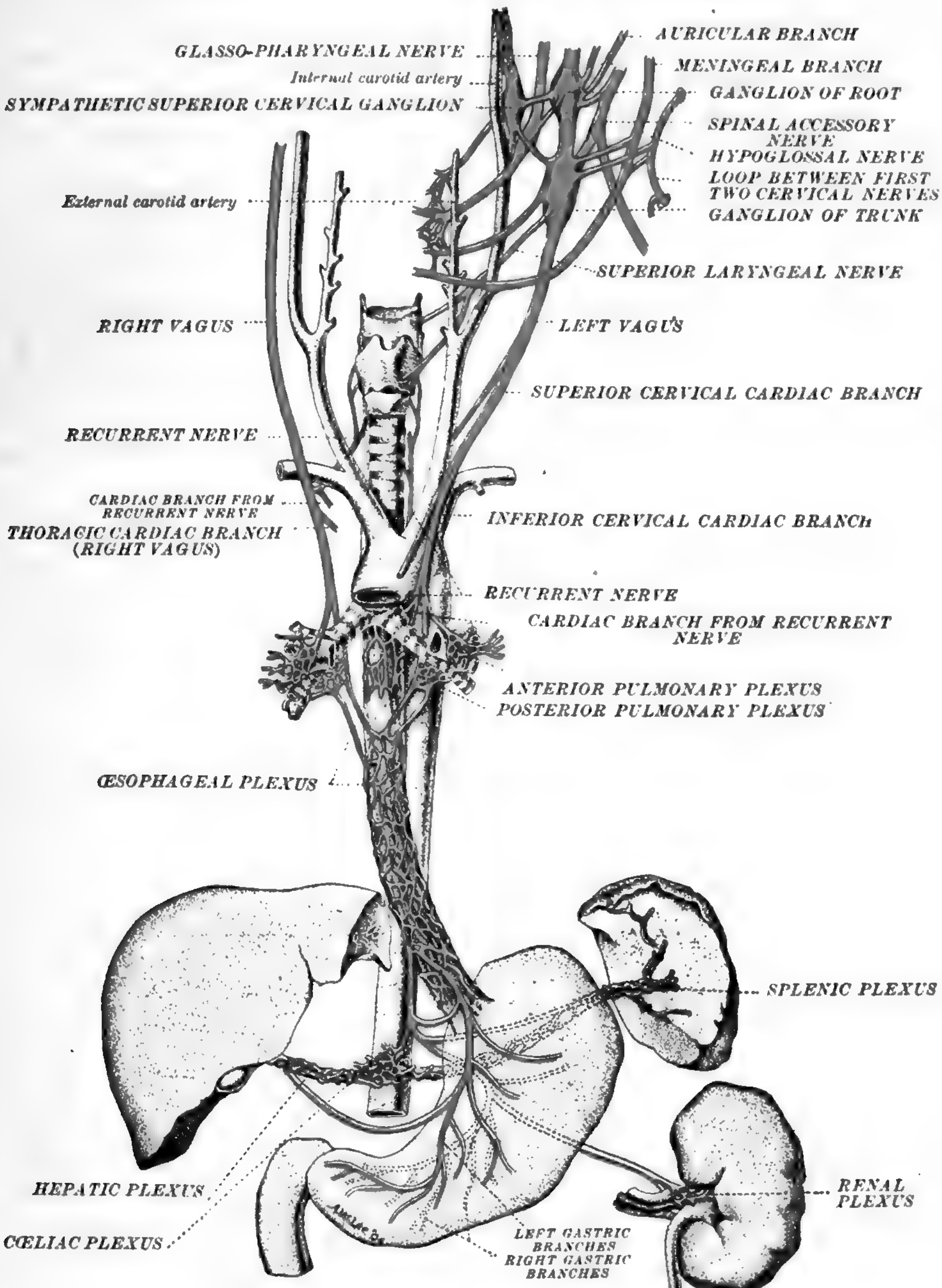
The vagus or pneumogastric nerves are the longest of the cranial nerves, and they are remarkable for their almost vertical course, their asymmetry, and their extensive distribution, for, in addition to supplying the lung and stomach, as the name 'pneumo-gastric' indicates, each nerve gives branches to the external ear, the pharynx, the larynx, the trachea, the œsophagus, the heart, and the abdominal viscera. Each nerve is attached to the side of the medulla, in the postero-lateral sulcus, behind the olivary body, by from twelve to fifteen root filaments which are in linear series with the filaments of the glosso-pharyngeal nerve. The filaments pierce the pia mater, from which they receive sheaths, and, traced outwards, they pass into the posterior fossa of the cranium towards the jugular foramen and unite to form the trunk of the nerve, which passes through openings in the arachnoid and the dura mater which are common to it and to the eleventh nerve. In the jugular foramen a small spherical ganglion, the jugular ganglion, is interposed in the trunk of the nerve, which here turns at right angles to its former course and descends through the neck. As it leaves the jugular foramen it is joined by the internal or accessory portion of the eleventh nerve, and immediately below this junction it enters a large ovoid ganglion, the ganglion nodosum or ganglion of the trunk (fig. 707). As it descends through the neck the nerve passes ventral and somewhat lateral to the superior cervical sympathetic ganglion, and in front of the longus capitis and longus colli, from which it is separated by the prevertebral fascia. In the upper part of the neck it is placed between the internal carotid artery and the internal jugular vein, and on a plane dorsal to them, the artery being ventral and mesial, and the vein ventral and lateral. In the lower part of the neck it occupies a similar position in regard to the common carotid artery and the internal jugular vein, and the three structures are enclosed in a common sheath derived from the deep cervical fascia, but within the sheath each structure occupies a separate compartment (fig. 707). In the root of the neck and in the thorax the relations of the nerves of the two sides of the body differ somewhat, and they must, therefore, be considered separately.

The right vagus passes in front of the first part of the right subclavian artery in the root of the neck and then descends in the thorax, passing obliquely downwards and backwards on the right of the trachea, and behind the right innominate vein and the superior vena cava, to the back of the root of the right lung. Just before it reaches the right bronchus it lies close to the inner side of the vena azygos as the latter hooks forwards over the root of the lung. At the back of the right bronchus the right vagus breaks up into a number of branches which anastomose with the branches of the sympathetic to form the **right posterior pulmonary plexus,** and from this plexus it issues in the form of one or more cords which descend on the œsophagus and break up into branches which anastomose with branches of the left vagus, forming the **posterior œsophageal plexus.** At the lower part of the thorax fibres of this plexus become again associated in one trunk which passes through the diaphragm on the *posterior* surface of the œsophagus, and is distributed to the *posterior* surface of the stomach and to the cœliac (solar) plexus and its offsets.

The **left vagus** descends through the root of the neck between the carotid and subclavian arteries and in front of the thoracic duct. In the upper part of the superior mediastinum it is crossed in front by the left phrenic nerve, and in the lower part of the same region it crosses in front of the root of the subclavian artery and the arch of the aorta and behind the left superior intercostal vein. Below the aortic

arch it passes behind the left bronchus and divides into branches which unite with twigs of the sympathetic to form the **left posterior pulmonary plexus.** From this plexus the fibres of the left vagus issue as one or more cords that break up into anastomosing branches to form the anterior **œsophageal plexus.** At the lower part

Fig. 706.—Diagram of the Branches of the Vagus Nerves.



of the thorax this plexus becomes a single trunk, which passes through the diaphragm on the *anterior* surface of the œsophagus, and it is distributed to the *anterior* surface of the stomach and to the liver.

The **Jugular Ganglion (Ganglion of the Root)** is a spherical grey mass about five

millimetres in diameter which lies in the jugular foramen (fig. 706). It is connected with the spinal accessory nerve and with the superior cervical sympathetic ganglion, and it gives off an auricular branch, by means of which it becomes connected with the facial and glosso-pharyngeal nerves, and a recurrent meningeal branch.

The **Ganglion Nodosum** (**Ganglion of the Trunk**) lies below the base of the skull and in front of the upper part of the internal jugular vein. It is of flattened ovoid form and about seventeen millimetres long and four millimetres broad (figs. 706 and 707). It is connected with the accessory part of the eleventh nerve, with the twelfth nerve, with the superior cervical ganglion of the sympathetic, and with the loop between the first two cervical nerves, and it gives off a pharyngeal, a superior laryngeal, and a superior cardiac branch.

Communications.—The vagus nerve is connected with the ninth, eleventh, and twelfth nerves, with the sympathetic, and with the loop between the first and second cervical nerves.

(1) Two communications exist between the tenth and ninth nerves: one between their trunks, just below the base of the skull, and one, in the region of their ganglia, consisting of one or two filaments. When two filaments are present one passes from the jugular ganglion and the other from the auricular nerve to the petrous ganglion of the glosso-pharyngeal nerve. Either or both of these filaments may be absent.

(2) Two twigs pass from the eleventh nerve to the ganglion nodosum, and at a lower level the accessory part of the eleventh nerve also joins the same ganglion (fig. 706). The majority of the fibres of the accessory part of the eleventh nerve merely pass across the surface of the ganglion and are continued into the pharyngeal and superior laryngeal branches of the vagus, but a certain number blend with the trunk of the vagus and are continued into its recurrent laryngeal and cardiac branches.

(3) Two or three fine filaments connect the ganglion nodosum with the twelfth nerve as the latter turns around the lower part of the ganglion (fig. 706).

(4) Fibres pass from the superior cervical ganglion of the sympathetic to both ganglia of the vagus (fig. 706).

(5) A twig sometimes passes from the loop between the first two cervical nerves to the ganglion nodosum (fig. 706).

Terminal Branches.—These are the meningeal, auricular, pharyngeal, superior laryngeal, inferior laryngeal, cardiac, bronchial, pericardial, œsophageal, and the abdominal branches.

(1) The **meningeal** or **recurrent branch** is a slender filament which is given off from the jugular ganglion. It takes a recurrent course through the jugular foramen, and is distributed to the dura mater around the transverse (lateral) sinus.

(2) The **auricular branch,** or **nerve of Arnold,** arises from the jugular ganglion in the jugular foramen. It receives a branch from the petrous ganglion of the glosso-pharyngeal, enters the petrous part of the temporal bone through a foramen in the outer wall of the jugular fossa, and communicates with the facial nerve or merely lies in contact with it as far as the stylo-mastoid foramen. It usually leaves the temporal bone by the stylo-mastoid foramen, but it may pass through the tympano-mastoid fissure, and it divides, behind the pinna, into two branches, one of which joins the posterior auricular branch of the facial while the other supplies sensory fibres to the posterior and inferior part of the external auditory meatus and the back of the pinna. It also supplies twigs to the osseous part of the external auditory meatus and to the lower part of the outer surface of the membrana tympani.

(3) The **pharyngeal branches** may be two or three in number. The principal of these joins the pharyngeal branch of the glosso-pharyngeal on the outer surface of the internal carotid artery, and after passing with the latter internal to the external carotid artery it turns downwards and inwards to reach the posterior aspect of the pharynx. Here the two nerves are joined by branches from the superior cervical ganglion of the sympathetic, with which they form the **pharyngeal plexus** (figs. 706 and 707). Branches from this plexus supply sensory fibres to the mucous membrane of the pharynx and motor fibres to the constrictores pharyngis, levator palatini, uvulæ, glosso-palatinus, and pharyngo-palatinus.

(4) The **superior laryngeal nerve** arises from the lower part of the ganglion nodosum, and passes obliquely downwards and inwards behind and internal to both internal and external carotid arteries towards the larynx. In this course it describes a curve with the convexity downwards and outwards and divides into (i) a larger internal and (ii) a smaller external branch (fig. 706). Before its division it is joined

by communications from the sympathetic and from the pharyngeal plexus, and it gives a small branch to the internal carotid artery.

(a) The **internal branch** accompanies the superior laryngeal artery to the interval between the upper border of the thyreoid cartilage and the great cornu of the hyoid bone. It passes under cover of the thyreo-hyoid muscle and pierces the hyo-thyreoid membrane to gain the interior of the pharynx, where it lies in the outer wall of the sinus piriformis and divides into a number of diverging branches. The ascending branches supply the mucous membrane on both surfaces of the epiglottis, and probably that of a small part of the root of the tongue. The descending branches ramify in the mucous membrane lining the larynx, and supply the mucous membrane which covers the back of the cricoid cartilage. One of the descending branches passes downwards on the internal muscles of the larynx to anastomose with the terminal part of the inferior (recurrent) laryngeal nerve.

(b) The **external branch** runs downwards on the inferior constrictor to the lower border of the thyreoid cartilage, where it ends, for the most part, in the crico-thyreoideus. A few filaments pierce the crico-thyreoid membrane and are distributed to the membrane lining the larynx. It occasionally gives off a cardiac branch which joins one of the cardiac branches of the sympathetic; it also furnishes twigs to the inferior constrictor, and communicating twigs to the pharyngeal plexus, and it receives a communication from the superior cervical ganglion of the sympathetic.

(5) The **recurrent (inferior** or **recurrent laryngeal) nerve** of the **right side** arises at the root of the neck in front of the first stage of the right subclavian artery. It hooks around the artery, passing below and then behind that vessel, and runs upwards and slightly inwards, crossing obliquely behind the common carotid artery (fig. 706). Having gained the side of the trachea, it runs upwards in the groove between that canal and the œsophagus, accompanied by branches of the inferior thyreoid artery, and, near the level of the lower border of the cricoid cartilage, becomes the inferior laryngeal nerve. In its course the recurrent nerve gives off branches to the trachea, **œsophageal** branches to the œsophagus and pharynx, and, near its commencement, one or more **inferior cardiac** branches. It communicates with the inferior cervical sympathetic ganglion and with the superior laryngeal nerve.

The **inferior laryngeal nerve,** the continuation of the recurrent, ascends between the trachea and œsophagus, enters the larynx under cover of the inferior constrictor of the pharynx, and divides into two branches, anterior and posterior. The *anterior branch* passes upwards and forwards on the crico-arytænoideus lateralis and thyreo-arytænoideus, and supplies these muscles and also the vocalis, arytænoideus obliquus, ary-epiglotticus, and thyreo-epiglotticus. The *posterior branch,* passing upwards, supplies the crico-arytænoideus posterior and arytænoideus obliquus, and anastomoses with the internal branch of the superior laryngeal nerve.

On the **left side** the recurrent nerve arises in front of the aortic arch and winds around the concavity of the arch lateral to the ligamentum arteriosum. It crosses obliquely behind the root of the left common carotid artery, gains the angular interval between the œsophagus and trachea, and corresponds with the nerve of the right side in the remainder of its course and distribution (fig. 706).

(6) **Cardiac branches.**—Of these, there are two sets, the superior and inferior. All the branches of both sets pass to the deep part of the cardiac plexus except a superior branch on the left side that passes to the superficial part of the cardiac plexus.

(a) The **superior (superior** and **inferior cervical) cardiac nerves** arise from the vagus and its branches in the neck (figs. 706 and 718). Some of these branches on both sides join with the cardiac branches of the sympathetic in the neck and pass with them to the cardiac plexus. Some on the right side pass independently through the thorax to the deep part of the cardiac plexus, and a branch on the left side passes through the thorax to the superficial part of the cardiac plexus.

(b) The **inferior (thoracic) cardiac branches.**—These branches on the right side arise in part from the recurrent nerve and in part from the main trunk of the vagus, while on the left side they usually arise entirely from the recurrent. All these branches pass to the deep part of the cardiac plexus (figs. 706 and 718).

(7) The **bronchial (pulmonary) branches** are anterior and posterior (fig. 706).

(a) The **anterior bronchial (pulmonary) branches** consist of a few small branches which arise at the upper border of the root of the lung. They pass forwards to gain the anterior aspect of the bronchus, where they communicate with the

sympathetic and form the **anterior pulmonary plexus,** from which fine twigs pass along the bronchus.

(b) The **posterior bronchial (pulmonary) branches.**—Almost the entire remaining trunk of the nerve divides into these branches, which communicate with branches from the second, third, and fourth thoracic ganglia of the sympathetic to form the **posterior pulmonary plexus** (fig. 706). The plexuses of the two sides communicate freely behind the bifurcation of the trachea, and branches from the plexus pass along each bronchus into the lung.

(8) The **pericardial branches** pass from the trunk of the vagus or from the bronchial or œsophageal plexuses to the anterior and posterior surfaces of the pericardium.

(9) **Œsophageal branches,** given off by the trunk of the nerve above the bronchial plexuses and from the œsophageal plexuses lower down, pass to the wall of the œsophagus.

(10) **Abdominal branches.**—The terminal part of the left vagus divides into many branches, some of which communicate freely along the lesser curvature of the stomach with filaments from the gastric plexus of the sympathetic, and to some extent with branches of the right vagus, to form the elongated **anterior gastric plexus** (fig. 706). From this plexus as well as from the nerve-trunk, **gastric branches** are given to the anterior surface of the stomach. **Hepatic branches** from the trunk or from this plexus pass in the lesser omentum to the hepatic plexus (fig. 706). The terminal part of the right vagus divides into many branches, and forms along the lesser curvature of the stomach an elongated **posterior gastric plexus** by communications with branches from the gastric plexus of the sympathetic and with branches from the right vagus. **Gastric branches** are given off by the trunk of the nerve and from this plexus. **Cœliac branches** are given by the trunk to the cœliac (solar) plexus, and **splenic** and **renal branches,** either directly or through the cœliac (solar) plexus, are given to the splenic and renal plexuses (fig. 706).

The **Sensory Fibres** of the vagus are processes of the cells of the jugular ganglion and the ganglion nodosum. The dendrites of the cells pass peripherally and the axones centrally. The latter enter the medulla in the filaments of attachment in the postero-lateral sulcus, and, in the reticular formation, they bifurcate into ascending and descending branches which end in the nuclei of termination of the vagus, namely, in the nucleus alæ cinereæ in the floor of the fourth ventricle and in the nucleus tractus solitarii.

The **Motor Fibres** spring from the nucleus ambiguus and join the sensory fibres in the reticular formation.

Central Connections.—The central connections of the vagus are similar to those of the glosso-pharyngeal nerve (fig. 598). Van Gehuchten's observations point to the conclusion that a part of the nucleus of the ala cinerea is a motor nucleus common to the ninth and tenth nerves, and that the only nucleus of termination of the tenth nerve is that of the tractus solitarius. By way of the tractus solitarius, the sensory fibres of the vagus are probably associated with the cells of the cervical segments of the spinal cord which give origin to the phrenic nerve and to motor fibres supplying other muscles of respiration.

THE ELEVENTH NERVE—THE SPINAL ACCESSORY

The spinal accessory nerve is exclusively motor. It consists of two parts, the accessory or superior, and the spinal or inferior part.

The fibres of the **accessory or superior portion** spring chiefly from the nucleus ambiguus, in common with the motor fibres of the vagus, and they pass through the reticular formation to the postero-lateral sulcus of the medulla, where they emerge as a series of filaments, below those of the vagus. The filaments pierce the pia mater and unite, as they pass outwards in the posterior fossa of the cranium, to form a trunk which enters the aperture in the dura mater common to the tenth and eleventh nerves. In the aperture this trunk is joined by the spinal portion of the nerve.

The **spinal** or **inferior portion** arises from the ventro-lateral cells of the ventral horn of the cord as low as the fifth, and rarely the seventh, cervical nerve. The fibres pass dorsalwards and lateralwards from their origins through the posterior part of the ventral horn and through the lateral funiculus of white substance, and they emerge from the lateral aspect of the cord behind the ligamentum denticulatum, along an oblique line, the lower fibres passing out immediately behind the ligament, and the upper close to and sometimes in association with the dorsal roots of the upper

two spinal nerves. As the spinal fibres pass out of the surface of the cord they unite to form an ascending strand which enters the posterior fossa of the cranium, through the foramen magnum, and, turning outwards, blends more or less intimately with the accessory portion. Thus combined, the nerve enters the jugular foramen in company with the vagus, but here it is again separated into its internal and external branches, which contain chiefly the same fibres as the original superior and inferior parts.

The **internal branch,** or accessory portion of the nerve, gives one or more filaments of communication to the jugular ganglion (ganglion of the root of the vagus), and then joins either the trunk of the vagus directly or its ganglion nodosum, the fibres of the branch being contributed to the pharyngeal, laryngeal, and cardiac branches of the vagus. Fibres corresponding to the white rami communicantes, absent in the cervical nerves, probably enter the cervical sympathetic ganglion through this ramus.

The **external branch** or the spinal portion runs backwards and downwards under cover of the posterior belly of the digastric and the sterno-mastoid. It usually crosses in front of and to the outer side of the internal jugular vein and between it and the occipital artery; then it pierces the sterno-mastoid, supplies filaments to it, and anastomoses in its substance with branches of the second cervical nerve. It emerges from the posterior border of the sterno-mastoid slightly above the level of the upper border of the thyreoid cartilage, passes obliquely downwards and backwards across the occipital portion of the posterior triangle, and disappears beneath the trapezius about the junction of the middle and lower thirds of the anterior border of that muscle (fig. 707). In the posterior triangle it receives communications from the third and fourth cervical nerves, and beneath the trapezius its fibres form a plexus with other branches of the same nerves. Its terminal filaments are distributed to the trapezius and they can be traced almost to the lower extremity of that muscle.

Central Connections.—The nuclei of origin, like other motor nuclei, are connected with the somæsthetic area of the cortex cerebri by the pyramidal fibres, and they are associated with the sensory nuclei of other cerebral nerves by the medial longitudinal fasciculus, and the fibres of the fasciculi proprii.

THE TWELFTH NERVE—THE HYPOGLOSSUS

The **hypoglossal nerves** are exclusively motor; they supply the genio-hyoidei and the extrinsic and intrinsic muscles of the tongue except the glosso-palatini. The fibres of each nerve issue from the cells of an elongated nucleus which lies in the floor of the central canal in the lower half of the medulla and in the floor of the fourth ventricle in the upper half beneath the trigonum hypoglossi. This nucleus is the upward continuation of the ventral group of cells of the ventral horn of the spinal cord. From their origin the fibres run ventralwards and somewhat lateralwards, probably joined in the medulla by a few fibres from the nucleus ambiguus which is a segment of the upward prolongation of the lateral group of cells of the ventral horn. The conjoined fibres issue from the medulla in the sulcus between the pyramid and the olivary body, in a series of from ten to sixteen root filaments, which pierce the pia mater and unite with each other to form two bundles (fig. 698). These bundles pass forwards and outwards to the hypoglossal (anterior condyloid) foramen, where they pierce the arachnoid and dura mater. In the outer part of the foramen the two bundles unite to form the trunk of the nerve. At its commencement, at the base of the skull, the trunk of the hypoglossus lies on the inner side of the vagus, but as it descends in the neck it turns gradually around the back and the outer side of the latter nerve, lying between it and the internal jugular vein, and a little above the level of the hyoid bone it bends forwards, and crosses external to the internal carotid artery, the root of origin of the occipital artery, the external carotid, and the loop formed by the first part of the lingual artery (fig. 707). After crossing the lingual artery it proceeds forwards on the outer surface of the hyo-glossus, crossing to the inner side of the posterior belly of the digastric, and the stylo-hyoid muscles. It disappears in the anterior part of the submaxillary region between the mylo-hyoid and the hyo-glossus, and divides into its terminal branches between the latter muscle and the genio-glossus.

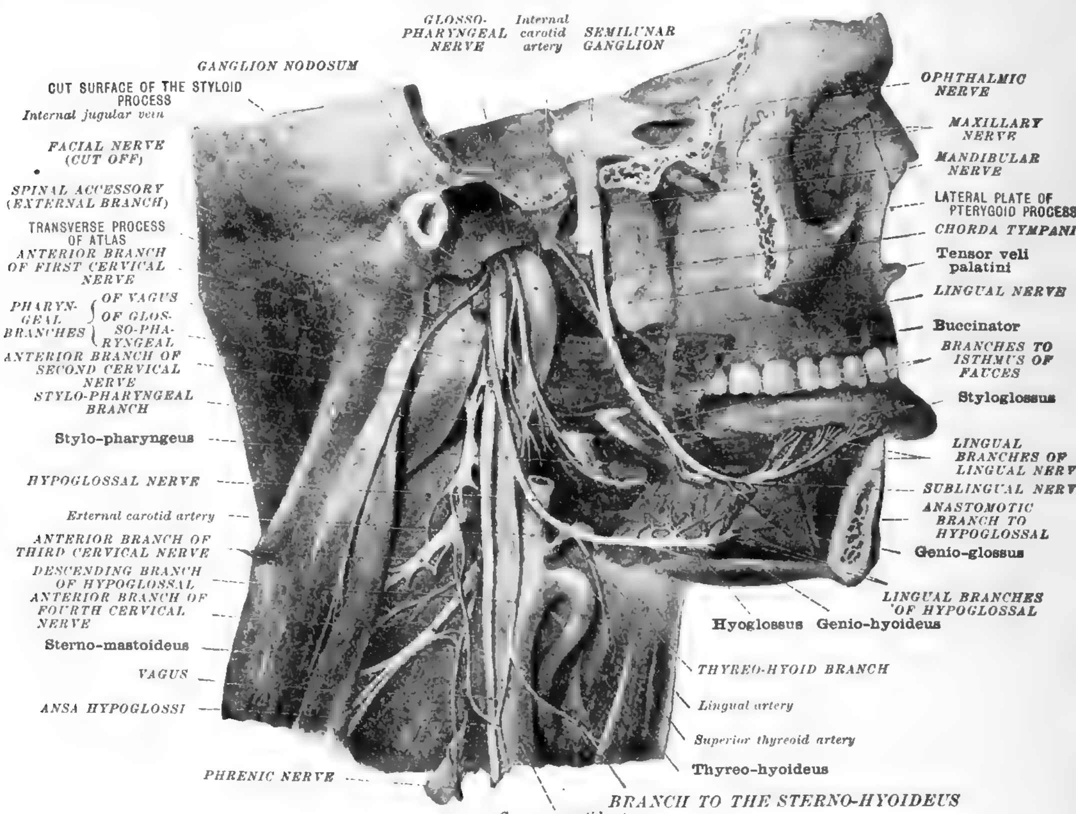
As it descends in the neck the trunk lies deeply between the internal jugular vein

and the internal carotid artery under cover of the parotid gland, the styloid muscles, and the posterior belly of the digastric, and it is crossed superficially by the posterior auricular and the occipital arteries. As it turns forwards around the root of the occipital artery the sterno-mastoid branch of that vessel hooks downwards across the nerve, and as it runs forwards on the hyo-glossus muscle it lies immediately above the ranine vein. It is crossed by the posterior belly of the digastric and the stylo-hyoid muscle, and it is covered superficially, behind the mylo-hyoid, by the lower part of the submaxillary gland.

Communications.—The hypoglossus is connected with the first cervical ganglion of the sympathetic, with the ganglion nodosum of the vagus, with the loop between the first and second cervical nerves, and with the lingual nerve; the latter communication is established along the anterior border of the hyo-glossus (figs. 706 and 707).

Terminal Branches.—(1) A meningeal branch, frequently represented by two fila-

Fig. 707.—The Hypoglossal, Glosso-pharyngeal, and Lingual Nerves. (Spalteholz.)



ments, is given off in the hypoglossal (anterior condyloid) canal. It passes backwards into the posterior fossa of the cranium and is distributed to the dura mater. It was believed at one time that the fibres of the meningeal branch were derived from the lingual nerve, but it is now deemed more probable that they are fibres from the cervical nerves, the sympathetic, or the vagus.

(2) **Branches which consist of Fibres derived from the Cervical Plexus.**—The descendens hypoglossi and the muscular twig to the thyreo-hyoid muscle, though apparently arising from the twelfth nerve, consist entirely of fibres which have passed into the hypoglossal nerve from the loop between the first two cervical nerves.

(a) The **descendens hypoglossi** parts company with the hypoglossus at the point where the latter hooks around the occipital artery (fig. 707). It runs downwards and slightly inwards on the sheath of the great vessels (occasionally within the sheath), and is joined at a variable level by branches from the second and third

cervical nerves, forming with them a loop, the ansa hypoglossi (fig. 707). The **ansa hypoglossi** may be placed at any level from a point immediately below the occipital artery to about four centimetres above the sternum. A twig to the **anterior belly of the omo-hyoid** arises from the descendens hypoglossi in the upper part of its course. The nerves which supply the **sterno-hyoid, sterno-thyreoid,** and **posterior belly of the omo-hyoid** are given off by the ansa hypoglossi. Twigs from the first two nerves pass downwards in the muscles behind the manubrium sterni and in rare cases communicate with the phrenic nerve within the thorax. The nerve to the posterior belly of the omo-hyoid runs in a loop of the cervical fascia below the central tendon of the muscle.

(b) The **nerve to the thyreo-hyoid** is given off near the tip of the great cornu of the hyoid bone, and runs obliquely downwards and inwards to reach the muscle.

(3) The **true hypoglossal branches,** the **rami linguales,** supply the stylo-glossus, hyo-glossus, genio-glossus, the genio-hyoid, and the intrinsic muscular fibres of the tongue.

The **nerve to the stylo-glossus** is given off near the posterior border of the hyo-glossus. It pierces the stylo-glossus, and its fibres pursue a more or less recurrent course within the muscle.

The **nerves to the hyo-glossus** are several twigs which are supplied to the muscle as the hypoglossal nerve crosses it.

The **nerves to the genio-glossus** and **genio-hyoid** arise under cover of the mylo-hyoid in common with the terminal branches to the intrinsic muscles of the tongue. They communicate freely with branches of the lingual, forming long loops which lie on the genio-glossus. From these loops twigs pass into the genio-glossus and into the muscular substance of the tongue. It is not improbable that the fibres to the genio-hyoid are really derived from the cervical nerves.

Central Connections.—The nucleus of origin of the hypoglossus is associated with the somæsthetic area (operculum) of the cortex cerebri of the opposite side by the pyramidal fibres, and it is connected with the sensory nuclei (nuclei of termination) of other cranial nerves by the medial longitudinal fasciculus.

THE DISTRIBUTION OF THE CUTANEOUS BRANCHES OF THE SENSORY AND MIXED CRANIAL AND SPINAL NERVES

The cutaneous filaments of the sensory and mixed nerves are distributed to definite regions of the surface of the body which are known as 'cutaneous areas.' Each cutaneous area has one special nerve of supply and the central part of the area receives that nerve alone, but wherever the borders of two areas meet they reciprocally overlap, therefore each margin of every cutaneous area has two nerves of supply, its own nerve and that of an adjacent area, and of these, sometimes one and sometimes the other preponderates.

The Cutaneous Areas of the Scalp

The limits of the cutaneous areas in the scalp region are indicated in figs. 708, 710, but in general terms it may be said that the skin of the scalp in front of the pinna is supplied by four cutaneous nerves, viz., the mesial part by the supratrochlear and the supra-orbital branches of the first division of the trigeminus, and the lateral part by the temporal branch of the second division, and the auriculo-temporal branch of the third division of the same nerve.

The portion of the scalp behind the pinna also receives four cutaneous nerves; laterally it is supplied by the great auricular and small occipital branches of the cervical plexus which contain filaments from the second and third cervical nerves, and medially it receives the great and smallest occipital nerves which are derived from the internal branches of the posterior primary divisions of the second and third cervical nerves respectively.

The Cutaneous Areas of the Face

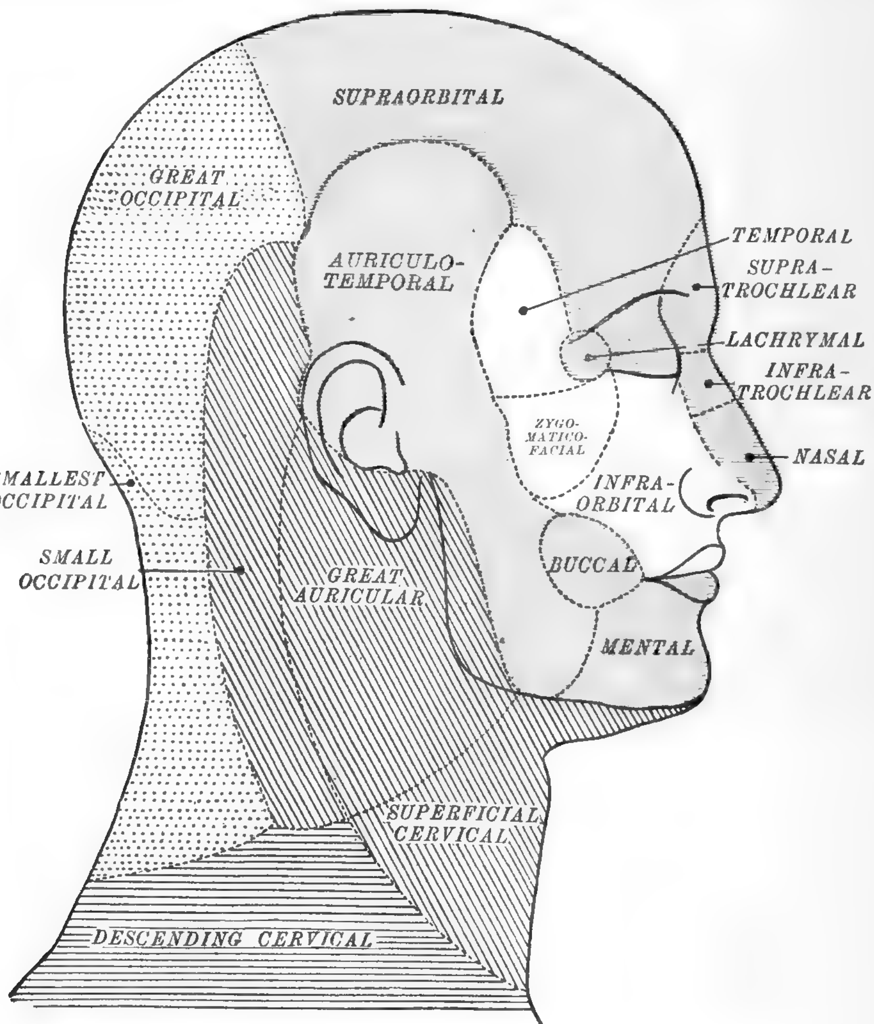
With the exception of the skin over the posterior part of the masseter muscle the whole of the skin of the face is supplied by the branches of the trigeminus. The

nose is supplied medially by the supratrochlear, the infratrochlear, and the nasal branches of the first division, and laterally by the infra-orbital branch of the second division. The upper eyelid is supplied by the supratrochlear, the supra-orbital, and the lachrymal branches of the first division; the lower eyelid by the infratrochlear branch of the first division and by the infra-orbital and the zygomaticofacial (malar) branches of the second division. The skin over the upper jaw and the

FIG. 708.—DIAGRAM OF THE CUTANEOUS NERVE AREAS OF THE HEAD AND NECK.

Red—First division of trigeminus. White—Second division of trigeminus.
Blue—Third division of trigeminus.

Dark shading—Posterior primary divisions of cervical nerves.
Oblique shading—Ascending and transverse superficial branches of cervical plexus.
Transverse shading—Descending superficial branches of cervical plexus.
It must be remembered that the boundaries of each area are not distinct; wherever two areas meet they overlap.



zygomatic (malar) bone is supplied by the infra-orbital and zygomatico-facial branches of the second division, that over the buccinator by the buccal branch of the third division, and that over the lower jaw, from before backwards, by the mental, buccal, and auriculo-temporal branches of the third division, except a small part near the posterior border which receives its supply from the great auricular nerve.

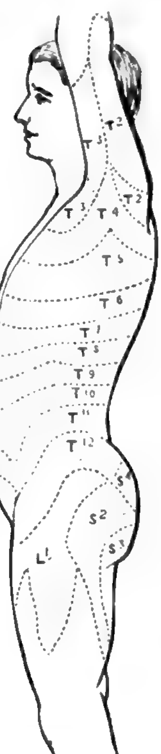
The Cutaneous Areas of the Pinna

The upper two-thirds of the outer surface of the pinna are supplied by the auriculotemporal branch of the third division of the trigeminus, and the lower third by twigs of the great auricular nerve. The lower three-fourths of the cranial surface of the pinna are supplied by the great auricular nerve, and the upper fourth by the small occipital nerve. The posterior surface of the external auditory meatus receives filaments from the auricular branch of the vagus.

The Cutaneous Areas of the Neck

The skin over the anterior part of the neck is supplied by the superficial cervical branch of the cervical plexus, which contains filaments of the second and third cervical nerves, and, in the lower part of its extent, by the anterior supra-clavicular nerves (suprasternal branches) which convey twigs of the third and fourth cervical nerves (fig. 708). The lateral part of the neck receives filaments from the second, third, and fourth cervical nerves by way of the great auricular, small occipital, and middle supraclavicular (supra-clavicular) branches of the cervical plexus, and posteriorly the skin of the neck is supplied by the small occipital nerve and by the internal branches of the posterior primary divisions of the cervical nerves from the second to the sixth inclusive (fig. 710).

Fig 709.—Diagram of the Cutaneous Areas of the Side of the Body and Part of the Limb. (After Head.)



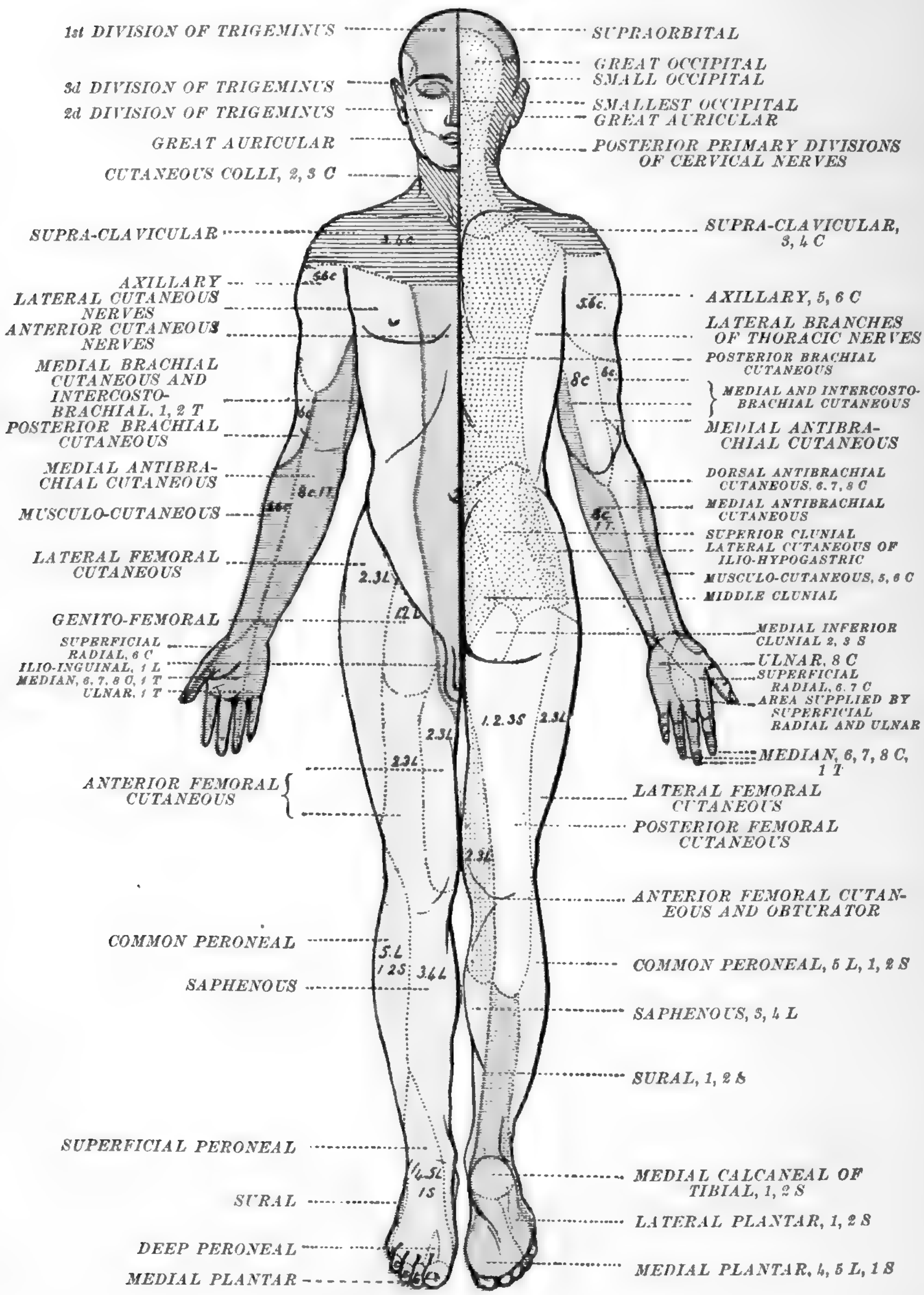
The Cutaneous Areas of the Trunk

The skin over the ventral aspect of the trunk as far down as the third rib is supplied by the anterior supra-clavicular (suprasternal) and middle supra-clavicular (supra-clavicular) branches of the cervical plexus, which contain filaments from the third and fourth cervical nerves (fig. 710). From the third rib to the lower part of the abdominal wall it receives the anterior cutaneous branches, and the anterior divisions

FIG. 710.—DIAGRAM SHOWING AREAS OF DISTRIBUTION OF CUTANEOUS NERVES.

HEAD:—
Red—First division of trigeminus. White—Second division of trigeminus. Blue—Third division of trigeminus. Dark area—Posterior primary divisions of cervical nerves. Oblique and transverse shading—Branches of cervical plexus.

BODY AND LIMBS:—
Red—Anterior branches of anterior primary divisions. Blue—Posterior branches of anterior primary divisions. Two colours in one area indicate that the area is supplied by two sets of nerves, and it should be remembered that wherever two nerve areas approach each other they overlap. The dotted blue area of the small sciatic indicates that the nerve comes from the posterior as well as from the anterior parts of the anterior primary divisions of the sacral nerves, but it supplies a flexor area. The area of the perforating cutaneous nerve is left uncoloured, because its true nature is uncertain. Dark shading—Posterior primary divisions. The numbers and initial letters refer to the respective spinal nerves from which the nerves are derived.



of the lateral cutaneous branches of the thoracic nerves except the first, second, and twelfth (fig. 710). The skin over the lower and anterior part of the abdominal wall is supplied by the ilio-hypogastric branch of the first lumbar nerve.

The cutaneous supply of the lateral aspects of the body is derived from the lateral branches of the anterior primary divisions of the thoracic nerves from the second to the eleventh, and the skin over the dorsal aspect of the body is supplied laterally by the posterior divisions of the lateral branches of the thoracic nerves from the third to the eleventh, and medially by the posterior primary divisions of the thoracic nerves, in the upper half by their medial branches and in the lower half principally by their lateral branches.

THE CUTANEOUS NERVE-SUPPLY OF THE LIMBS

The areas of skin of the upper and lower limbs which are supplied by the branches of the brachial, lumbar, and sacral plexuses are indicated in fig. 710, and the spinal nerves which contribute to each nerve are noted. The question of the skin areas supplied by any given spinal nerve is one of great clinical importance, in connection with the diagnosis of injuries of nerves and of pathological conditions affecting them. Therefore, considerable attention has been directed to the matter and it has been found that the areas which become hypersensitive when certain spinal nerve-roots are irritated, or insensitive when the roots are destroyed, do not correspond exactly with the regions to which the fibres of the roots can apparently be traced by dissection. Moreover, it has been discovered, partly by clinical observations on the human subject and partly by experiment on monkeys, that the nerves of the limbs have a more or less definite segmental distribution. To understand clearly this segmental arrangement the reader must remember that in the embryonic stage when no limbs are present the body is formed of a series of similar segments, each of which is provided with its own nerve. At a later stage when the limbs grow outwards, each limb is formed by portions of a definite number of segments which fuse together into a common mass of somewhat wedge-like outline. Each rudimentary limb possesses a dorsal and a ventral surface. The dorsal surfaces of both the upper and the lower limbs are originally the extensor surfaces, and the ventral surfaces the flexor surfaces, but, as the upper limb rotates outwards and the lower limb rotates inwards as development proceeds, in the adult, the extensor surface of the upper limb becomes the dorsal surface, and the extensor surface of the lower limb, the ventral surface. The preaxial border of the upper limb is the radial or thumb border, and the postaxial border, the ulnar or little finger border. The preaxial border of the lower limb is the tibial or great toe border, and the postaxial border, the fibular or little toe border. As projections of the segments of the body grow out to form the limbs each projection carries with it the whole or part of the nerve of the segment to which it belongs, and therefore the number of body segments which take part in a limb is indicated by the number of spinal nerves which pass into it. If these facts are remembered it will naturally be expected (1) that the highest spinal nerves passing into a limb will be associated with its preaxial portion and the lowest with its postaxial portion; (2) that the highest and lowest segments in each limb area will take a smaller part in the formation of the limb than the middle segments; and (3) that, consequently, the highest and lowest nerves will pass outwards into the limb for a shorter distance than the middle nerves. Observers are not yet in perfect agreement as to the exact distribution of each nerve, but the reader who studies the diagrams on pages 991 to 997, which are modified from the figures published by Head and Thorburn as records of the results of their clinical observations, will have no difficulty in recognising a dorso-ventral segmental arrangement in the lower portions of both the upper and lower limbs. In the upper parts of the lower limbs, however, the original segmental distribution appears to be masked. This may be due (1) partly to the fact that the areas recognisable by clinical phenomena do not correspond exactly with the areas to which definite dorsal root-fibres are distributed, but rather to definite segments of the grey substance of the spinal cord with which the root-fibres are connected; (2) partly to the overlapping of segments and the acquired preponderance of one nerve over another in the overlapping areas, and (3) partly to the incompleteness of the data which are at our disposal in the case of the human subject. Sherrington has proved that in the monkey the sensory

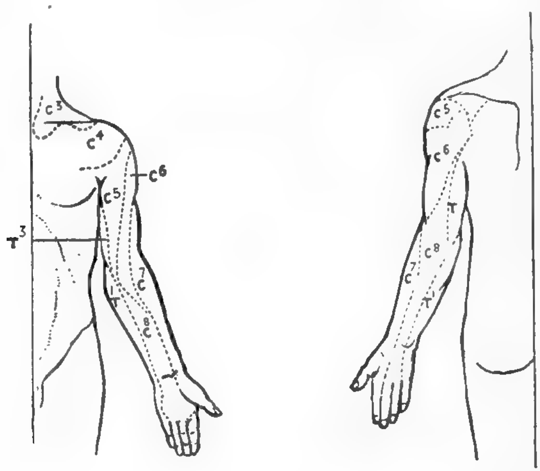
areas of the limbs are arranged in serial correspondence with the spinal nerves, the middle nerves of each limb series passing to the distal extremity while the higher and lower nerves are limited to the proximal regions. Thorburn's observations, which differ from Head's, are, especially as regards the upper limb, in close conformity with the results obtained by Sherrington's experiments on monkeys.

The Cutaneous Areas of the Upper Limb

The skin over the upper third of the deltoid muscle is supplied by the posterior supra-clavicular (supra-acromial) and middle supra-clavicular (supra-clavicular) nerves, which are branches of the cervical plexus containing fibres of the third and fourth cervical nerves, and that over the lower two-thirds by the axillary (circumflex) nerve which conveys fibres of the fifth and sixth cervical nerves (fig. 710).

The skin over the front of the upper arm is supplied externally by the axillary (circumflex) nerve above, and below by the superior branch of the dorsal antibrachial cutaneous, the external cutaneous branch of the radial (musculo-spiral) nerve. The former contains filaments of both the fifth and sixth cervical nerves, and the latter filaments of the sixth alone. The skin of the inner side of the upper arm is supplied by the medial antibrachial cutaneous (internal cutaneous) nerve with

Fig. 711.—Diagram of the Cutaneous Areas of the Upper Extremity. (Modified from Head.)



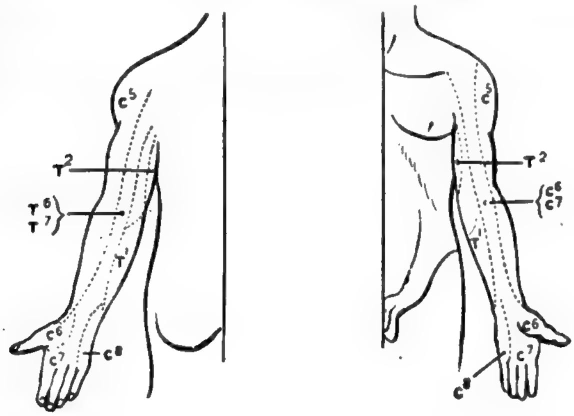
fibres of the eighth cervical and first thoracic nerves, and by the medial brachial cutaneous (lesser internal cutaneous) and intercosto-brachial (intercosto-humeral) nerves which are derived from the first and second thoracic nerves. The back of the upper arm is supplied, externally, by the fifth and sixth cervical nerves through the axillary (circumflex) nerve and by the dorsal antibrachial cutaneous; the middle portion, by the eighth cervical nerve through the posterior brachial cutaneous, the internal cutaneous branch of the radial (musculo-spiral) nerve; and the inner portion by the first and second thoracic nerves through the medial brachial cutaneous (lesser internal cutaneous) nerve, and the intercosto-brachial (intercosto-humeral) nerve (fig. 710).

The front of the forearm is divided into two areas, an outer, which is supplied by the fifth, sixth, and possibly the seventh cervical nerves, through the musculo-cutaneous branch of the brachial plexus, and an inner, supplied by the eighth cervical and first thoracic nerve through the medial antibrachial cutaneous (internal cutaneous) nerve. On the back of the forearm there are three areas:—(1) an outer, supplied by fibres of the fifth and sixth cervical nerves through the musculo-cutaneous nerve; (2) a middle, which receives fibres of the sixth, seventh, and eighth cervical nerves through the lower branch of the dorsal antibrachial cutaneous of the radial (inferior external cutaneous branch of the musculo-spiral nerve), and (3) an inner which receives the eighth cervical and first thoracic nerves through the medial antibrachial cutaneous (fig. 710).

The front of the hand is supplied by the sixth, seventh, and eighth cervical nerves and by the first thoracic nerve through the superficial radial (radial) nerve, and through the median and ulnar nerves. The superficial radial supplies the radial side of the thumb by its palmar cutaneous branch. The remainder of the palm and the palmar aspects of the fingers are supplied by the median and ulnar nerves through their palmar cutaneous and digital branches, the median supplying three and a half digits and the ulnar the remaining one and a half (fig. 710).

The dorsal aspect of the hand is supplied by the sixth, seventh, and eighth cervical nerves, which reach it through the superficial radial (radial) and through the median

Fig. 712.—Diagram of the Cutaneous Areas of the Upper Extremity. (After Thorburn.)



and ulnar nerves. The superficial radial supplies the outer part of the dorsum and the outer three and a half digits, except the lower portions of the second, third, and half of the fourth digits, which receive twigs from the median nerve; the ulnar nerve supplies the ulnar half of the dorsum of the hand, including the inner one and a half digits. The areas supplied by definite spinal nerves, according to the observations of Head and Thorburn, are shown in figures 711 and 712 respectively.

The Cutaneous Areas of the Lower Extremity

There are six cutaneous areas in the region of the buttock, three upper and three lower. Of the upper areas the outer is supplied by the anterior primary divisions of the last thoracic and first lumbar nerves through the iliac branches of the last thoracic and the ilio-hypogastric nerves; the middle upper area receives the lateral divisions of the posterior primary branches of the upper three lumbar nerves, and the inner upper area is supplied by twigs from the lateral branches of the posterior primary divisions of the upper two or three sacral nerves (fig. 710).

Of the lower three areas, the outer receives filaments from the second and third lumbar nerves through the lateral femoral cutaneous (external cutaneous) branch of the lumbar plexus; the middle area is supplied by the first, second, and third sacral nerves through the posterior femoral cutaneous (small sciatic) nerve; and the inner area by the second and third sacral nerves through the medial inferior clunial (perforating cutaneous) branch of the sacral plexus (fig. 710).

On the back of the thigh there are three areas. The inner and the outer are supplied by the second and third lumbar nerves, the former through the lateral femoral cutaneous (external cutaneous) branch of the lumbar plexus, and the latter through the anterior cutaneous branches of the femoral (internal cutaneous branch of the anterior crural) nerve. The middle area receives twigs from the first, second, and third sacral nerves through the posterior femoral cutaneous (small sciatic), a branch of the sacral plexus.

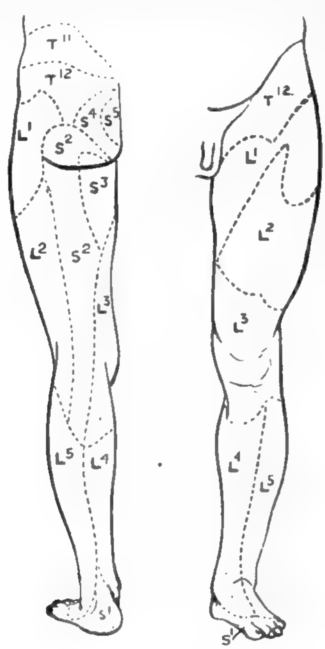
The front of the thigh is supplied by the first, second, and third lumbar nerves, and there are five cutaneous areas. The outer area receives twigs of the second and third lumbar nerves through the lateral (external) cutaneous nerve. There are

two mesial areas, an upper and a lower. The former is supplied by the lumbo-inguinal (crural) branch of the genito-femoral (genito-crural), which conveys twigs of the first and second lumbar nerves; the latter receives fibres of the second and third lumbar nerves through one of the anterior (middle) cutaneous branches of the femoral (anterior crural) nerve. The small upper and inner area is supplied by the first lumbar nerve through the ilio-inguinal, and the lower inner area receives twigs of the second and third lumbar nerves through one of the anterior cutaneous branches (internal cutaneous) of the femoral (anterior crural) nerve (fig. 710).

The front of the knee is supplied by the second, third, and fourth lumbar nerves through the anterior (middle and internal) cutaneous and saphenous (long saphenous) branches of the femoral (fig. 710).

Of the skin over the region of the popliteal space, the inner portion receives fibres from the second, third, and fourth lumbar nerves through the anterior (internal) cutaneous branch of the femoral (anterior crural) nerve and through the superficial division of the obturator nerve; the middle and lateral portion receives twigs of the first three sacral nerves through the posterior cutaneous (small sciatic) nerve (fig. 710).

Fig. 713.—Diagram of the Cutaneous Areas of the Lower Extremity. (After Head.)



The skin over the front and inner side of the leg is supplied by the third and fourth lumbar nerves through the saphenous nerve, and the skin of the front and outer side of the leg receives nerve-fibres from the fifth lumbar, and the first and second sacral nerves through the sural cutaneous (fibular communicating) branch of the common peroneal (external popliteal) nerve. The skin of the lower and middle part of the front of the leg is supplied by the superficial peroneal (musculo-cutaneous) nerve which conveys filaments of the fourth and fifth lumbar and the first sacral nerve (fig. 710).

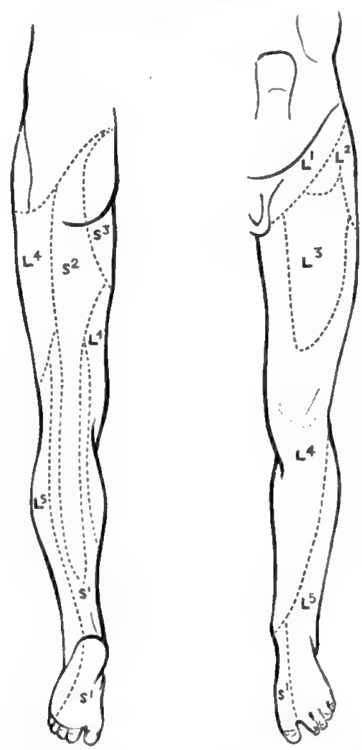
In the skin of the back of the leg five areas can be distinguished, two inner, upper and lower, two middle, upper and lower, and an outer area. The upper inner area is supplied by the second, third, and fourth lumbar nerves through an anterior cutaneous branch (internal cutaneous) of the femoral (anterior crural) nerve and the superficial branch of the obturator nerve. The lower inner area receives filaments from the third and fourth lumbar nerves through the saphenous nerve. The upper middle area is supplied by the first, second, and third sacral nerves

through the posterior femoral cutaneous (small sciatic) nerve, and the lower middle area by the first and second sacral nerves through the sural (external saphenous) nerve. The outer area is supplied by the fifth lumbar and the first and second sacral nerves through the lateral sural cutaneous (fibular communicating) of the common peroneal (external popliteal) nerve (fig. 710).

The skin of the dorsum of the foot is supplied principally by the fourth and fifth lumbar and by the first sacral nerves; the majority of the nerve-fibres travel by the superficial peroneal (musculo-cutaneous) nerve, but the adjacent sides of the first and second toes are supplied by the femoral (anterior crural) nerve and the outer side of the dorsum of the little toe is supplied by the first and second sacral nerves through the sural (external saphenous) (fig. 710).

The skin of the region of the heel is supplied by the first and second sacral nerves, the inner surface and inner part of the under surface by the medial calcaneal branches of the tibial (calcaneo-plantar) nerve and the posterior, external, and lower aspects by the sural (external saphenous) nerve (fig. 710).

Fig. 714.—Diagram of the Cutaneous Areas of the Lower Extremity. (After Thorburn.)



The sole of the foot in front of the heel receives cutaneous fibres from the last two lumbar and the first two sacral nerves; the inner area, which includes the inner three and a half digits, being supplied by the medial plantar nerve which conveys fibres of the fourth and fifth lumbar and the first sacral nerves; and the outer area by the first and second sacral nerves through the lateral plantar nerve.

The inner side of the foot is supplied by the third and fourth lumbar nerves through the saphenous nerve and the outer side by the first and second sacral nerves through the sural (external saphenous) nerve (fig. 710).

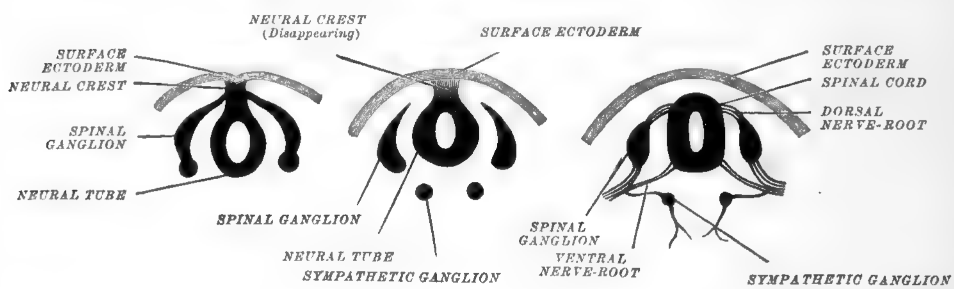
The skin of the scrotum and penis is supplied by the first lumbar nerve through the ilio-inguinal nerves, and the second and third sacral nerves through the perineal and dorsal penile branches of the pudendal (pudic) nerve (fig. 710).

The cutaneous areas of the lower extremity which have been demarcated by Head and Thorburn are shown in figs. 713 and 714.

THE SYMPATHETIC SYSTEM

The so-called sympathetic system is that portion of the nervous system which is especially concerned in the distribution of impulses to the glandular tissues, to the muscle of the heart, and to the non-striated muscular tissue of the body wherever found. Since these tissues are most abundant in and largely comprise the viscera or splanchnic organs of the body, the largest and most evident of the structures comprising the sympathetic system are found either in or near the cavities containing the viscera. However, the finer divisions of the system ramify throughout the whole body, supplying vaso-motor fibres to the blood-vessels throughout their course, controlling the glands of the skin, and supplying pilo-motor fibres for the hairs, forming intrinsic plexuses within the walls of the viscera, and certain of its fibres convey impulses towards the central system (sensory sympathetic neurones). While it is very probable that certain of the simpler reactions of the splanchnic organs may be mediated by the sympathetic system alone, yet the sympathetic is by no means independent of the cerebro-spinal system, but is rather, both anatomically and functionally, merely a part of one continuous whole. Throughout, it shares its domain of termination with cerebro-spinal fibres, chiefly of the sensory variety, and most of its rami and terminal branches carry a few cerebro-spinal fibres towards their areas of distribution. Likewise the cerebro-spinal nerves carry numerous sympathetic fibres gained by way of rami connecting the two systems.

Fig. 715.—Diagram showing (1) the Growth of the Primitive Ganglia from the Neural Crest; (2) the Division of the Primitive Ganglia into Spinal and Sympathetic Portions, and (3) the Formation of the Nerves.



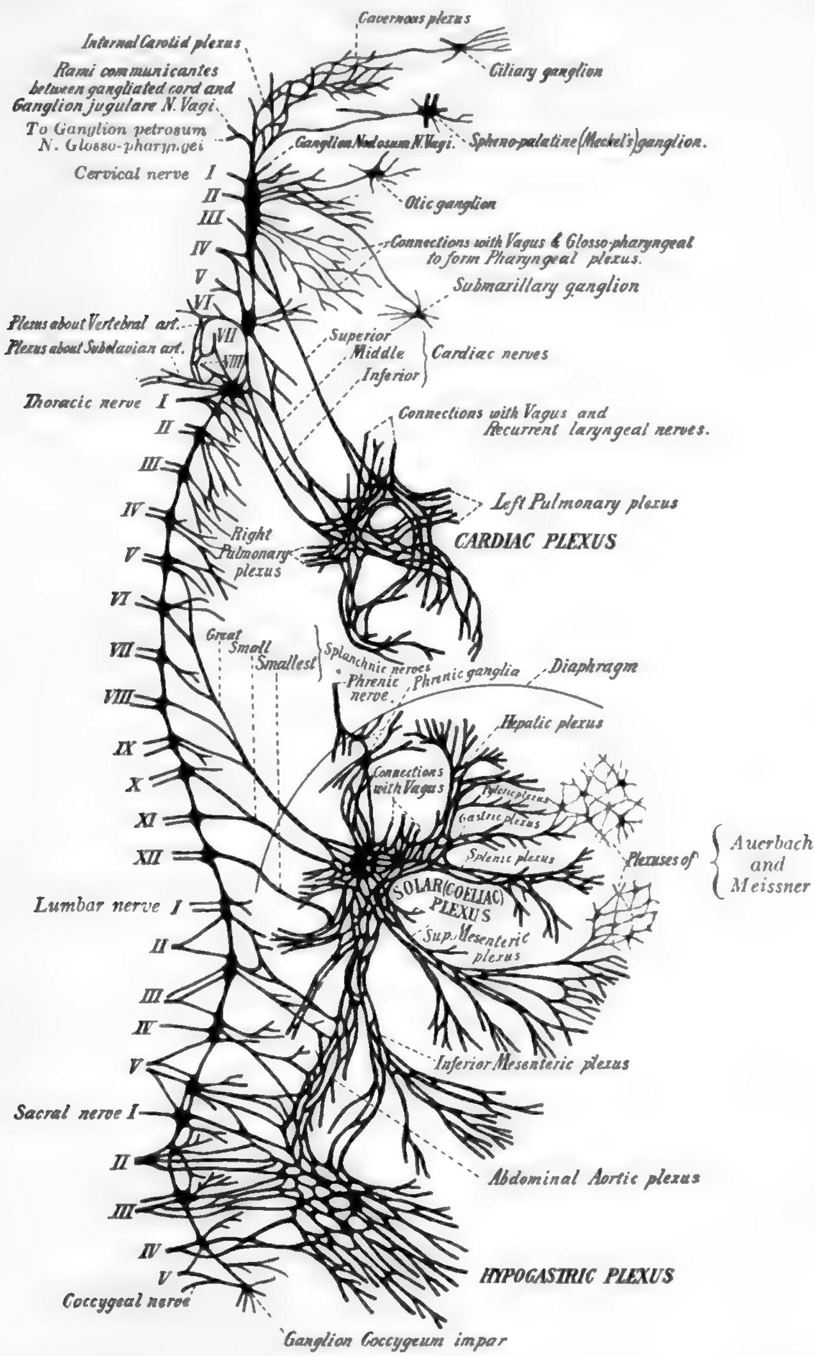
Like the cerebro-spinal system, the sympathetic consists of cell-bodies, each of which gives off one axone. In addition, the cell-bodies give off numerous dichotomously branched dendrites by which their receptive surfaces are increased, and they are accumulated into ganglia, large and small. The larger ganglia have more or less constant positions, shapes, and arrangements, while the smaller, some of which are microscopic, are scattered throughout the body in a seemingly more indefinite manner. The axones or fibres arising in these ganglia are given off in trunks and rami which connect the ganglia with each other or with the cerebro-spinal system, or which pass from the ganglia to be distributed directly upon their allotted elements.

The **sympathetic fibres** arising from the ganglia are, for the most part, either totally non-medullated or partially medullated. Some fibres are medullated near their cells of origin, but lose their medullary sheaths before reaching their terminations. Some of them possess complete medullary sheaths throughout, but in no cases are the sheaths as thick or well developed as is the rule with the cerebro-spinal fibres. Thus, nerve-trunks and rami in which sympathetic fibres predominate appear greyish in colour and more indefinite, as distinguished from those of the cerebro-spinal nerves, which always appear a glistening white, due to light being reflected from the myelin of the sheaths of their fibres.

Origin of the sympathetic system.—Not only must the cerebro-spinal and sympathetic systems be considered anatomically continuous and dependent, but also the neurones of the two systems have a common origin, namely, the ectoderm of the dorsal mid-line of the embryo. The cells of the neural crest (see p. 753) become arranged in segmental groups and soon separate into two varieties:—those which will

remain near the spinal cord and develope into the spinal ganglia, and those which, during the growth processes, migrate and become displaced further into the periphery and form the sympathetic ganglia.

FIG. 716.—SCHEME SHOWING GENERAL PLAN OF THE COARSER PORTIONS OF THE SYMPATHETIC NERVOUS SYSTEM AND ITS PRINCIPAL COMMUNICATIONS WITH THE CEREBRO-SPINAL SYSTEM. (After Flower, modified.)

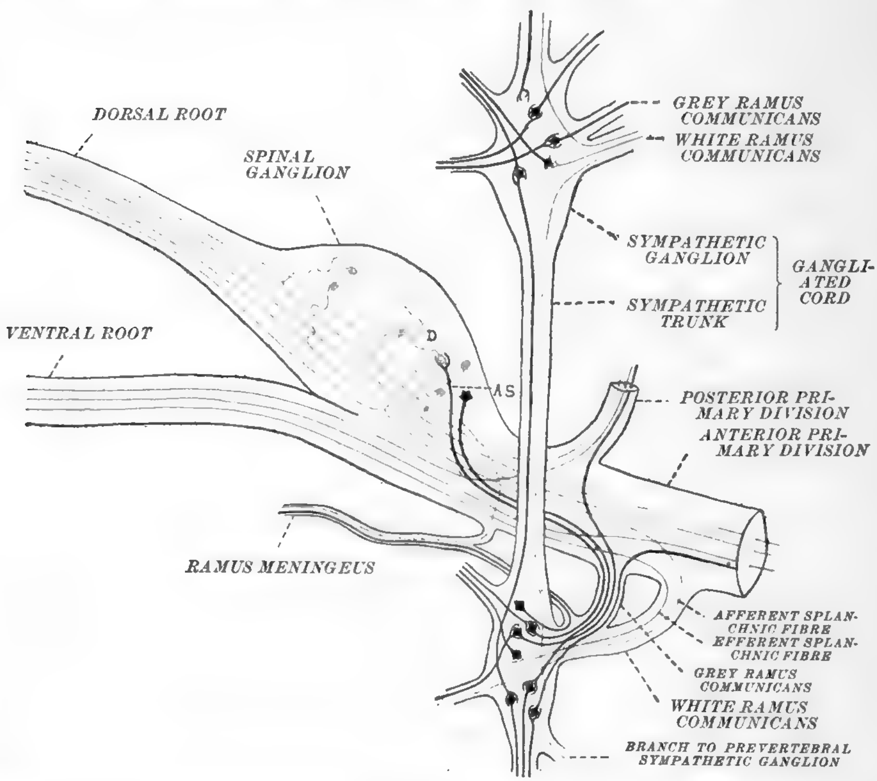


The migration from the vicinity of the central system occurs to varying extents, so that in the adult the cells comprise three general groups of ganglia situated

different distances away from the vertebral column:—(1) A large portion of the cells remain near the central system and form a linear series of ganglia which, with the trunks connecting them, become two *gangliated nerve-cords* extending along each side, proximal to and parallel with the vertebral column; (2) a still larger portion of the cells migrate further towards the periphery and are accumulated into ganglia which assume an intermediate position and which, with the rami connecting them with each other and with other structures, form a series of great *prevertebral plexuses;* (3) still other cells wander even further away from the locality of their origin and invade the very walls of the organs innervated by the sympathetic system. The latter cells occur as numerous small terminal ganglia, most of which are microscopic and which, with the twigs connecting them, form the most peripheral of the sympathetic plexuses. Examples of these are the intrinsic ganglia of the heart and pancreas and the *plexuses of Auerbach* and *Meissner* in the walls of the digestive canal. Small, straggling

FIG. 717.—SCHEME SHOWING THE CONNECTION BETWEEN THE SYMPATHETIC AND THE CEREBRO-SPINAL AND CENTRAL NERVOUS SYSTEMS.

AS, Afferent sympathetic fibres; D, Dogiel spinal ganglion-cell of type II.



ganglia may be found scattered between these three general groups. The supporting tissue of the sympathetic system accumulates early and is probably all of mesodermic origin.

Construction of the sympathetic system.—The sympathetic ganglia may be considered as relays in the pathways for the transmission of impulses from the region in which they arise to the tissues in which they are distributed; the cells composing the ganglia are the cell-bodies of the neurones interposed in the various neurone chains performing this function. A fibre arising from a cell-body in a given ganglion may pass out of the ganglion and proceed directly to its termination upon a smooth muscle-fibre or gland-cell, or it may pass through a connecting trunk to another ganglion and there terminate about and thus transmit the impulse to another cell, which, in its turn, may give off the fibre which bears the impulse to the appropriate tissue-element. Fibres arising in given ganglia may pass through other ganglia and proceed uninterrupted to their respective destinations. On the other hand, several

neurones may be involved in the transmission of a given impulse when sent from a region distant from the tissue to which it is distributed.

Communication between the central nervous system and the sympathetic is established through both efferent and afferent fibres. In the region of the spinal cord both varieties of fibres pass from one system to the other by way of the **rami communicantes,** delicate bundles of fibres connecting the nearby sympathetic trunk with the respective spinal nerves. The efferent fibres of the rami arise in the ventral horn of the spinal cord, emerge through the ventral roots, enter the rami, and terminate for the most part about the cells of the nearest sympathetic ganglion; some, however, may pass through or over the ganglion of the sympathetic cord and terminate about cells in more distant ganglia. Since these fibres transmit impulses from the central to the sympathetic system, they are known as **efferent splanchnic fibres.** They are of smaller size than is the average for the cerebro-spinal efferent or motor fibres of the ventral root. The **afferent splanchnic fibres** are of two varieties:—(1) Peripheral processes of the spinal ganglion-cells which run outwards in the nerve-trunk, enter the rami communicantes, pass through the various connecting trunks and terminal rami of the sympathetic and terminate in the tissues supplied by these rami. Such are merely sensory fibres of the cerebro-spinal type which collect impulses in the domain of the sympathetic and convey them to the central system by way of the sympathetic nerves and the dorsal roots of the spinal nerves. (2) Afferent sympathetic fibres proper. The actual existence of these has not been long established, and their relative abundance is as yet uncertain. They consist of fibres arising in the sympathetic ganglia which enter the spinal ganglia by way of the rami communicantes and the cerebro-spinal nerve-trunk and terminate in arborisations about the spinal ganglion-cells, chiefly about the Dogiel cells of type II (D, fig. 717). The afferent impulses transmitted by these sympathetic fibres are borne into the spinal cord by way of the cerebro-spinal fibres of the dorsal roots. They must necessarily either receive the impulses they bear from sympathetic neurones having both peripheral and central processes or they themselves must be axones or central processes of neurones having also processes terminating in the peripheral tissues.

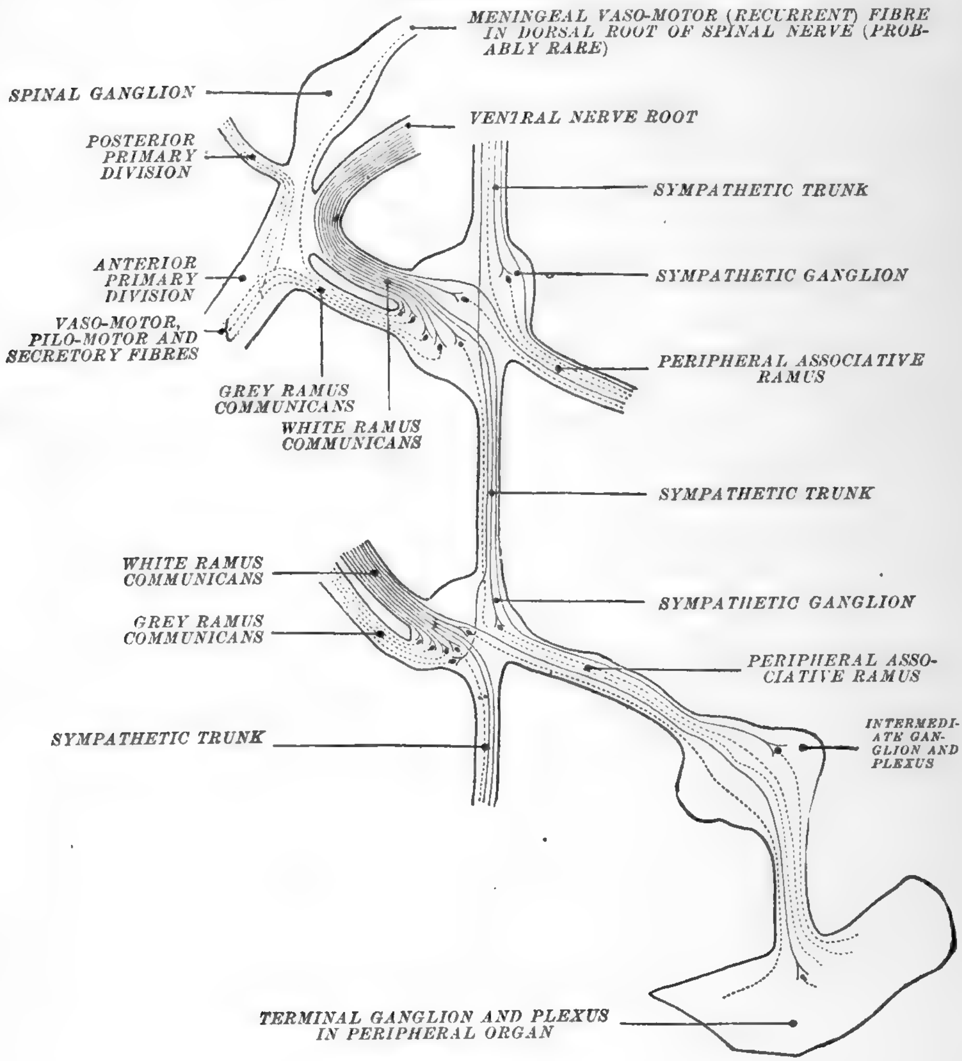
The thoracic and the lumbar spinal nerves are connected with the sympathetic trunk (gangliated cord) by two rami communicantes. Most of both the efferent splanchnic and also the afferent splanchnic fibres (which arise in the spinal ganglia) pass by way of a separate ramus. Both these varieties being of the cerebro-spinal type, and, therefore, medullated, they give the ramus a white appearance meriting the name **white ramus communicans.** Fibres of the sympathetic type predominate in the second ramus and thus it is the **grey ramus communicans.** The latter consists of:—(1) afferent sympathetic fibres and (2) of sympathetic fibres which join the primary divisions of the spinal nerves and course in them to their allotted tissues (fig. 717). In the sacral region, most of the efferent splanchnic fibres pass over the ganglia of the sympathetic trunk and terminate in the more peripheral ganglia of the plexuses of this region. This is especially true for the fibres passing from the second, third, and fourth sacral nerves. In the cervical region white rami are not in evidence, a fact probably explicable as due to an arrangement by which at least most of the efferent splanchnic fibres arising in the cervical segments of the spinal cord pass downwards in these segments and join the sympathetic through the white rami of the upper thoracic nerves; others may enter the cervical portion of the gangliated cord through the spinal accessory or eleventh cranial nerve, rather than through individual white rami. All the spinal nerves are joined by grey rami communicantes from the sympathetic trunk.

Vaso-motor fibres to the meninges and intrinsic blood-vessels of the spinal cord pass to the spinal nerves by way of the grey rami. Thence they may reach the meninges by one of three ways:—(1) through the delicate recurrent or meningeal branch of the spinal nerve (fig. 717); (2) through the trunk and ventral root of the spinal nerve; (3) probably more rarely, through the trunk and dorsal root of the spinal nerve (fig. 718).

Corresponding communications exist between the cranial nerves and the sympathetic, but these occur further towards the periphery and in not so regular a manner as the communications between the spinal nerves and the sympathetic system. The mesencephalon, for example, is chiefly connected with the ciliary ganglion of the sympathetic by fibres which are sent through the oculo-motor nerve and which enter this ganglion by way of its short root and terminate about its cells.

Splanchnic efferent fibres from the rhombencephalon pass outwards to the sympathetic in the roots of the facial, glosso-pharyngeal, vagus, and spinal accessory nerves, all of which have more or less irregularly disposed communicating rami. The ganglia of origin of the vagus, more than perhaps any other nerve, both give origin to and receive impulses from splanchnic efferent fibres. Likewise, twigs of other cranial nerves, especially of the trigeminus, connect with the small sympathetic ganglia of the head. The meningeal branches given by certain of the cranial nerves contain vaso-motor fibres, and these correspond to the sympathetic fibres in the recurrent branches and in the roots of the spinal nerves.

Fig. 718.—Diagram showing the Course and Connections of Sympathetic Nerve-fibres.



From the above it may be seen that the ganglia and connecting trunks and rami of the sympathetic system may be divided as follows:—(1) The two **sympathetic trunks** lying proximal to and parallel with the vertebral column; (2) the **great prevertebral plexuses,** of which there are roughly three, one in the thorax, one in the abdomen, and one in the pelvic cavity (fig. 716), each of which is subdivided; (3) the numerous **terminal ganglia and plexuses** situated either within or close to the walls of the various organs; (4) the **trunks** and **rami** connecting the ganglia with each other and thus contributing to the plexuses, or connecting the ganglia with

other nerves or with the organs with whose innervation they are concerned. The connecting trunks and rami may be divided into—(*a*) the *rami communicantes*, or *central branches*, connecting the sympathetic with the cerebro-spinal and central systems; (*b*) *associative trunks*, best considered as those which connect sympathetic ganglia situated on the same side of the body; (*c*) *commissural branches*, or those which connect ganglia situated on opposite sides of the mid-line of the body, such as the transverse connecting branches between the sympathetic trunk in the lumbo-sacral region (fig. 719), or all the connecting trunks between the ganglia of plexuses occupying the mid-region of the body; (*d*) *terminal* or *peripheral branches*, or those which pass from the ganglia to their final distribution apparently uninterrupted by other ganglia.

THE SYMPATHETIC TRUNKS

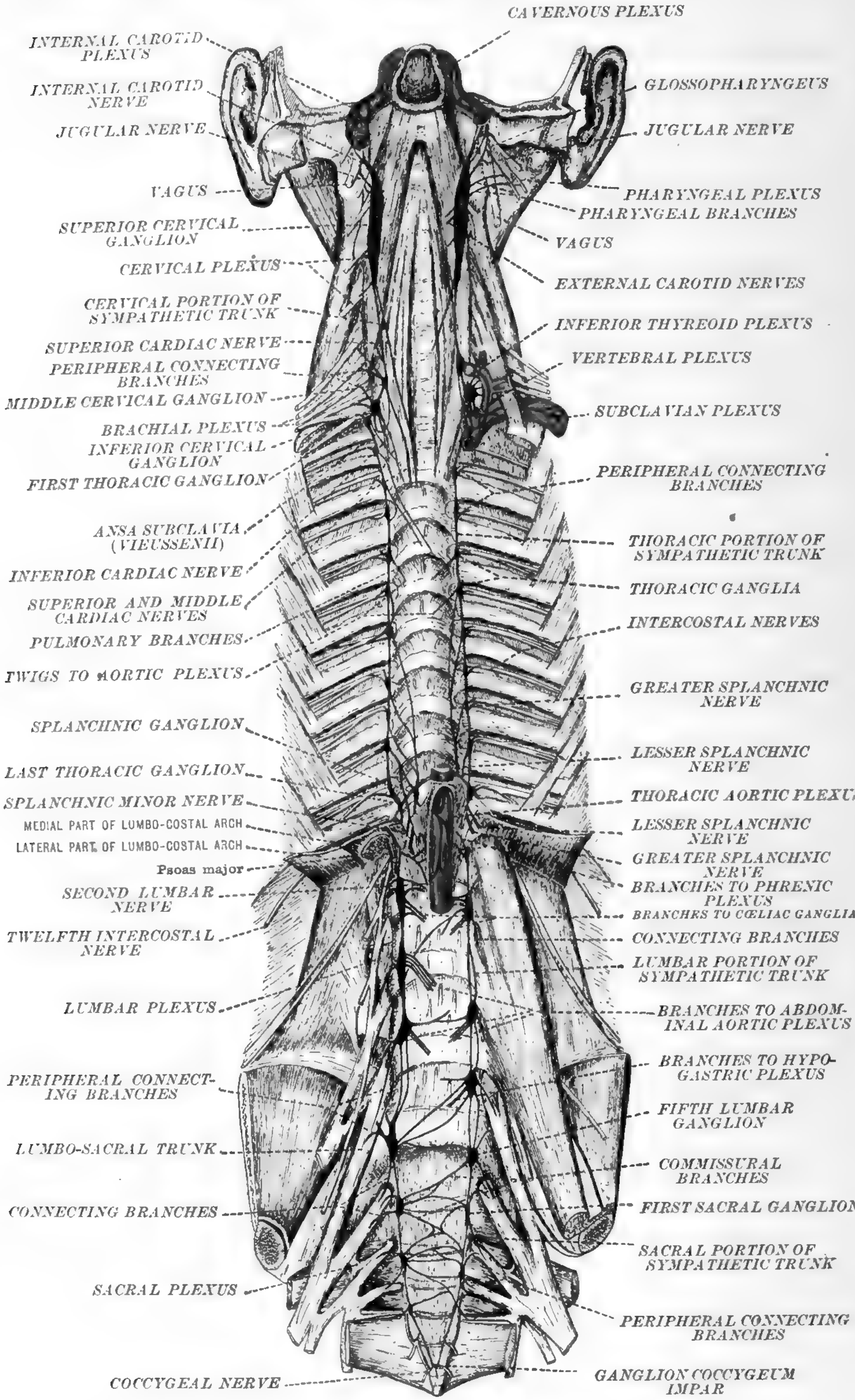
The sympathetic trunks, or gangliated cords, of the sympathetic system are two symmetrical trunks with ganglia interposed in them at intervals of varying regularity, and extending vertically, one on each side of the ventral aspect of the vertebral column, from the second cervical vertebra to the first piece of the coccyx. Upon the coccyx the two trunks unite and terminate in a single medial ganglion, the **ganglion coccygeum impar.** The various ganglia are connected with the spinal nerves by the rami communicantes. Morphologically, each trunk might be expected to possess thirty-one ganglia, one for each spinal nerve, but, owing to the fusion of adjacent ganglia in certain regions, especially the cervical, there are in the adult only twenty-one or twenty-two ganglia in each trunk. These occur as *three cervical ganglia, ten or eleven thoracic ganglia, four lumbar and four sacral ganglia*, and the *ganglion coccygeum impar*, which is common to both trunks.

In the cervical region the sympathetic trunks lie in front of the transverse processes of the vertebræ, from which they are separated by the longus capitis (rectus capitis anticus major) and longus colli; in the thoracic region they lie at the sides of the bodies of the vertebræ and on the heads of the ribs; in the lumbar region they are placed more ventrally with reference to the spinal nerves and more in front of the bodies of the vertebræ and along the ventral borders of the psoas muscles; in the pelvis the ganglia lie between and ventral to the openings of the sacral foramina. In the lower lumbar and sacral region one ganglion may send rami communicantes to two spinal nerves and one spinal nerve may be connected with two ganglia. The ganglia of the trunks throughout give off associative branches to the ganglia of the prevertebral plexuses and branches to the nearby viscera and blood-vessels. These branches may appear either white or grey according to the predominance of medullated or non-medullated fibres in them. In the lumbo-sacral region commissural or transverse connecting branches between the ganglia of the two trunks are especially abundant. In connecting trunks having a whiter appearance, the greater part of the medullated fibres producing it are fibres from the spinal nerves which have passed through the sympathetic ganglia without termination and are passing on their way to terminate about the cells of more distant ganglia situated either in the prevertebral plexuses or in the ganglia of the terminal plexuses. The trunks connecting the ganglia of the sympathetic trunks all contain three varieties of fibres:—(1) Fibres which have entered them in the white rami communicantes from the spinal nerves of higher or lower levels, and which are coursing in them to terminate in other ganglia, either in the trunks above or below or in ganglia not belonging to the trunks; (2) fibres arising in sympathetic ganglia of a higher or lower level and passing upwards or downwards to terminate in other ganglia of the trunk or to issue from the trunk and proceed to more peripheral ganglia or to ganglia of the opposite trunk (both associative and commissural fibres); (3) splanchnic afferent fibres or sensory fibres arising either in the spinal ganglia, or sensory sympathetic fibres arising in sympathetic ganglia and coursing in the trunk to pass into spinal ganglia above or below by way of the grey rami communicantes.

THE CEPHALIC AND CERVICAL PORTIONS OF THE SYMPATHETIC TRUNK

The cephalic portion of the sympathetic system consists of small ganglia and of numerous plexuses connected with the internal carotid nerve, the ascending branch

Fig. 719.—Showing the Sympathetic Trunks in their Relation to the Vertebral Column, to the Spinal Nerves, and to each Other. (Modified from Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



given off by the superior cervical sympathetic ganglion. The cephalic ganglia are all relatively small. There are four considered in the ordinary macroscopic dissections, namely, the ciliary or ophthalmic, the spheno-palatine or Meckel's ganglion, the otic, and the submaxillary. These ganglia with their roots or communicating branches have been described in detail in their connections with the divisions of the trigeminus and with the oculo-motor and facial nerves.

The internal carotid nerve, the **ascending branch** from the superior cervical sympathetic ganglion, may be regarded as an upward prolongation of the primitive sympathetic trunk. It arises from the upper end of the superior cervical ganglion and passes through the carotid canal into the cranial cavity. It divides into two branches which subdivide to form a coarse plexus, the *internal carotid plexus*, which partly surrounds the internal carotid artery before the latter enters the cavernous sinus (fig. 719). It passes with the artery to the cavernous sinus, where it forms the finer meshed *cavernous plexus.*

The **internal carotid plexus** supplies offsets to the artery and receives communicating branches from the tympanic plexus through the inferior carotico-tympanic nerve and from the spheno-palatine ganglion through the great deep petrosal nerve. It also communicates by fine branches with the semilunar (Gasserian) ganglion and with the sixth cranial nerve.

The **cavernous plexus** gives branches of communication to the oculo-motor and trochlear nerves and to the ophthalmic division of the trigeminus. According to Toldt and Spalteholz, it communicates with the **tympanic plexus** through the superior carotico-tympanic (small deep petrosal) nerve. It also communicates with the ciliary ganglion through the **long root** *of the ciliary ganglion.* These branches may pass through the superior orbital (sphenoidal) fissure either separately or with the naso-ciliary (nasal) nerve.

The cavernous plexus also gives branches to the carotid artery and filaments of the plexus accompany small branches of the artery to the hypophysis (pituitary body) and to the dura mater on the sphenoid bone.

The *terminal branches* of the cavernous plexus consist of delicate filaments that anastomose freely, forming fine plexuses, and pass from the cavernous plexus along the terminal divisions of the internal carotid artery and their branches. These fine plexuses take the name of the artery on which they lie. The four larger of them are the plexuses of the anterior and middle cerebral arteries, the plexus of the chorioid artery, and the ophthalmic plexus.

The **cervical portion of the sympathetic cord** extends upwards along the great vessels of the neck. No white rami communicantes connect it directly with the spinal cord, but instead it receives splanchnic efferent fibres from the upper thoracic spinal nerves through the sympathetic trunk, and probably also from the cervical spinal cord through the spinal accessory nerve and the connections with the vagus. It sends **grey rami communicantes** to each of the cervical nerves. It extends from the subclavian artery to the base of the skull, lying behind the sheath of the great vessels and in front of the longus capitis and longus colli, which separate it from the transverse processes of the cervical vertebræ (fig. 719). It usually has but three **ganglia,** one at each end, the superior and inferior, and one between these two, called the middle ganglion. The latter varies somewhat in position and is sometimes absent.

Superior Cervical Ganglion

The **superior cervical ganglion** is usually fusiform in shape and is sometimes marked by one or more constrictions. There is ground for the belief that it is formed by the coalescence of four ganglia corresponding to the first four cervical nerves. It varies from an inch to one and one-half inches (2·5 to 3·7 cm.) in length, lying behind the upper part of the sheath of the great vessels of the neck and in front of the transverse processes of the second and third cervical vertebræ. It occasionally extends upwards as high as the transverse process of the first vertebra (fig. 719). It is connected with the middle cervical ganglion by the intervening trunk, and it gives off a large number of communicating branches.

Communications:—(1) **Four grey rami communicantes** connect the ganglion with the anterior primary divisions of the first four cervical nerves.

(2) **Communicating branches to the cranial nerves.**—An irregular number of small twigs pass from the superior cervical ganglion to the hypoglossal nerve

and to the ganglion nodosum of the vagus. A named branch, the *jugular nerve,* runs upwards to the base of the skull and divides into two branches, one of which enters the jugular foramen and terminates in the jugular ganglion of the vagus, and the other ends in the petrous ganglion of the glosso-pharyngeus.

(3) **Four or five laryngo-pharyngeal branches** come from the superior ganglion and the plexus extending downwards from it, and pass forwards and inwards, external to the carotid vessels, to the wall of the pharynx, where they unite on the middle constrictor with the pharyngeal branches of the glosso-pharyngeus and vagus, forming with them the *pharyngeal plexus,* from which branches are distributed to the walls of the pharynx and to the superior and external laryngeal nerves (fig. 719).

(4) The **superior cervical cardiac nerve** springs from the lower part of the ganglion or from the trunk immediately below it. It passes downwards behind the carotid sheath, either in front of or behind the inferior thyreoid artery, and in front of the longus colli, and establishes communications with the upper cervical cardiac branch of the vagus, the middle cervical cardiac branch of the sympathetic, and with the inferior and external laryngeal nerves. At the root of the neck the nerve of the right side passes in front of or behind the first part of the right subclavian artery, and is continued along the innominate artery to the front of the bifurcation of the trachea, where it ends in the deep part of the cardiac plexus. The left nerve passes into the thorax along the front of the left common carotid artery, crosses the front of the arch of the aorta, immediately anterior to the vagus, and terminates in the superficial part of the cardiac plexus (fig. 720). Filaments from both the right and left nerves pass to the inferior thyreoid plexus.

(5) The **external carotid nerves** (fig. 719) pass forwards from the superior cervical ganglion to the external carotid artery, where they divide into branches which anastomose freely to form around the artery the **external carotid plexus.** This plexus extends to the beginning of the artery, and is continued upon the common carotid artery as the **common carotid plexus.** From the external carotid plexus, filaments pass to form secondary plexuses around each of the branches of the external carotid artery. These plexuses take the names of the arteries which they follow, namely, the **superior thyreoid plexus, lingual plexus,** etc. Filaments pass from the external carotid plexus to the *glomus caroticum* (the carotid gland), and from the superior thyreoid plexus to the thyreoid gland.

From the **external maxillary** (facial) **plexus** passes the *sympathetic root of the submaxillary ganglion.*

A part of the **internal maxillary plexus** is continued upon the middle meningeal artery as the **meningeal plexus.** From this plexus filaments pass to the otic ganglion, and sometimes a branch, called by English anatomists the **external superficial petrosal nerve,** passes to the geniculate ganglion of the facial nerve.

(6) Small **branches to the ligaments and bones** of the upper part of the vertebral column.

(7) The **internal carotid nerve** (**ascending branch**) has been described with the cephalic portion of the sympathetic system.

The Middle Cervical Ganglion

The **middle cervical ganglion** is small and somewhat triangular in outline. It is sometimes absent. Its position is variable, but it commonly lies about the level of the cricoid cartilage, in front of the bend of the inferior thyreoid artery (fig. 719), and it is connected with the superior cervical ganglion and with the inferior cervical ganglion by the trunk of the gangliated cord. From the lower part of the middle ganglion some filaments pass behind the subclavian artery, while others pass in front of and beneath that artery and anastomose with the first-mentioned filaments to form a loop, the **ansa subclavia** (*ansa Vieussenii*) (figs. 675 and 719). Filaments from this ansa to the inferior cervical ganglion thus form another communication between the middle and inferior cervical ganglia.

Connections.—The middle cervical ganglion gives off four or more connecting rami.

Two (*a* and *b*) are grey rami communicantes which connect the middle ganglion with the anterior primary branches of the fifth and sixth cervical nerves.

(*c*) One or more peripheral branches pass along the inferior thyreoid artery and

anastomose with branches from the superior and middle cardiac nerves and from the inferior cervical ganglion, thus taking part in the formation of the **inferior thyreoid plexus,** from which branches pass to the thyreoid gland.

(*d*) The **middle cardiac nerve** arises by one or more branches from the ganglion, or from the trunk of the cord, and passes downwards behind the common carotid artery and, on the right side, either in front of or behind the subclavian artery, and then along the innominate artery to the deep part of the cardiac plexus (figs. 719 and 720). It is frequently larger than the superior cardiac nerve. On the left side the nerve runs between the subclavian and common carotid arteries. On both sides the nerve communicates with the inferior laryngeal nerve and the external laryngeal nerve.

The middle cervical ganglion also gives branches to the common carotid plexus.

The Inferior Cervical Ganglion

The **inferior cervical ganglion** is irregular in form. It is larger than the middle cervical ganglion, and it lies deeply in the root of the neck behind the vertebral artery or the first part of the subclavian artery, and in front of the interval between the transverse processes of the last cervical and the first thoracic vertebræ (figs. 719 and 720). It is connected with the middle cervical ganglion by the sympathetic trunk, and by filaments passing to the ansa subclavia (Vieussenii), and it is either blended directly with the first thoracic ganglion or connected with it by a short stout portion of the trunk. It gives rami to the last two cervical nerves and peripheral branches to the vertebral and internal mammary arteries, to the heart, and to the inferior thyreoid plexus.

Connections.—(1) The rami to the seventh and eighth cervical nerves are **grey rami communicantes.**

(2) The **branches to the vertebral artery** are large and they unite with similar branches from the first thoracic ganglion to form a plexus, the **vertebral plexus** (fig. 719), which accompanies the artery into the posterior fossa of the cranium, where it is continued on the basilar artery. The plexus communicates in the neck by delicate threads with the cervical spinal nerves.

(3) The branches to the internal mammary artery form the **internal mammary plexus.**

(4) The **inferior cardiac nerve** may arise from the inferior cervical ganglion, from the first thoracic ganglion, or by filaments from both these ganglia (figs. 719 and 720). It communicates with the recurrent laryngeal nerve and with the middle cardiac nerve, and passes to the deep part of the cardiac plexus. On the left side it frequently joins the middle cardiac nerve to form a common trunk.

Construction of the cervical portion of the sympathetic trunk.—This portion of the trunk contains both medullated and non-medullated fibres, and a large part of the former are of spinal origin. In the absence of white rami communicantes to this portion of the sympathetic trunk, it is evident that few if any of the spinal or **efferent splanchnic fibres** are contributed to it below the superior ganglion by the cervical region of the spinal cord. Instead, such fibres are known to enter by way of the white rami from the upper thoracic nerves, and to ascend to this portion of the sympathetic trunk. Most of these fibres terminate about the cells of the superior, middle, and inferior cervical ganglia, and these cells in their turn give off sympathetic fibres which pass by way of the communicating branches mentioned above for the cephalic and cervical portions, to their distribution in the structures of the head, neck, and thorax. The efferent splanchnic fibres which terminate in the superior ganglion especially are among those which mediate—(1) vaso-motor impulses for the head; (2) secretory impulses for the submaxillary gland; (3) pilo-motor impulses for the hairs of the face and neck; (4) motor impulses for the smooth muscle of the eyelids and orbit, and (5) dilator impulses for the pupil. The sympathetic or grey fibres in the cervical portion of the sympathetic trunk arise from the cells of the upper thoracic and the cervical ganglia, and are passing either to connect the ganglia with each other or to enter the peripheral branches and proceed to their terminal distribution.

THE THORACIC PORTION OF THE SYMPATHETIC TRUNK

The thoracic part of the trunk runs downwards on the heads of the ribs from the first to the tenth, and then passes a little ventralwards on the sides of the bodies of the lower two vertebræ. Above it is continuous with the cervical portion at the root of the neck, behind the vertebral artery. Below it leaves the thorax dorsad to the medial lumbo-costal arch (arcuate ligament), or sometimes to the lateral lumbo-costal arch, and continues into the lumbar portion of the trunk. It lies behind the costal pleura and crosses over the aortic intercostal arteries.

The number of ganglia in this part of the trunk is variable. There are usually ten or eleven, but the first is sometimes fused with the inferior cervical ganglion and occasionally other ganglia fuse. The ganglia are irregularly angular or fusiform in shape, and lie on the head of the ribs, on the costo-vertebral articulations, or on the bodies of the vertebræ. The portions of the trunk connecting the ganglia usually are single, but sometimes they are composed of two or three small cords in juxtaposition. Each ganglion, with the possible exception of the first, receives a *white ramus communicans* from a thoracic nerve and all give off *grey rami communicantes* to these nerves.

The **white rami communicantes,** as they approach the sympathetic trunk, quite often appear double, due to the separation of a large portion of their fibres into two main streams, one passing upwards in the sympathetic trunk, and one passing downwards. Of the white rami from the upper five thoracic nerves, the upward stream of fibres is much larger than the downward, due to the fact that a greater part of the efferent splanchnic fibres from these nerves are distributed through the cervical portion of the sympathetic trunk, as noted above in the construction of that portion. Usually the white rami from the nerves pass directly to the corresponding ganglia of the trunk, and thus lie in company with the corresponding grey rami. Sometimes, however, they may join the intermediate portions of the trunk, and in the lower thoracic region especially, a ramus may pass from a nerve to the ganglion corresponding to the nerve above or below. The fibres of the white rami from the lower thoracic nerves are in greater part directed downwards in the sympathetic trunk, and also in its peripheral branches, to be distributed to the abdominal viscera. In all cases, however, some of the fibres of the thoracic white rami terminate in the ganglia nearest their junction with the trunk, while others pass into the nearest peripheral branches. In this way the white rami from all the thoracic spinal nerves, especially those of the mid-region, are directly concerned in the innervation of the thoracic viscera, lungs, œsophagus, aorta, etc.

The **first thoracic ganglion** is larger than the other ganglia of this region and is irregular in form. It may be narrowly ovoid or semilunar. It lies in front of the neck of the first rib, behind the pleura, and on the inner side of the costo-cervical trunk (superior intercostal artery); this vessel separates it from the prolongation of the portion of the first thoracic nerve which passes to the brachial plexus. It sometimes fuses with the inferior cervical ganglion, and, on the other hand, sometimes extends to the upper part of the second rib to fuse with the second thoracic ganglion. The result of the latter fusion resembles the stellate ganglion of the carnivora, and when it occurs, is sometimes referred to as the *ganglion stellatum.* When largely developed, the first ganglion sends a branch to the cardiac plexus, the fourth cardiac nerve of Valentin.

The **second thoracic ganglion,** triangular in shape and almost as large as the preceding, is sometimes placed on the costo-vertebral articulation, and is sometimes partly concealed by the first rib.

The **third to the ninth thoracic ganglia** are usually placed opposite the heads of the corresponding ribs, but the **tenth** and **eleventh** may lie on the bodies of the vertebræ.

The fibres passing from the ganglia form two groups of branches, the central and the peripheral.

The central branches are the **grey rami communicantes,** which pass from the ganglia to the corresponding spinal nerves. After they have united with the anterior primary divisions of the nerves, the fibres of these rami divide into four groups:—(1) Fibres which pass inwards along the roots of the nerves to supply the membranes of the spinal cord, or enter a meningeal or recurrent branch for the same purpose; (2) fibres which enter the spinal ganglion and terminate there (sensory

sympathetic fibres); (3) fibres which pass dorsalwards into the posterior primary divisions of the nerves; (4) fibres which pass outwards in the anterior primary divisions of the nerves. The last two groups of fibres are distributed to the blood-vessels of the body-walls, to the skin-glands, and to the muscles of the hairs of the body.

The **peripheral branches** form two series, an upper and a lower.

Those of the *upper series* pass from the upper four or five ganglia ventralwards and inwards to be distributed as follows:—

(1) **Pulmonary branches** which accompany the intercostal arteries towards their aortic origin without forming plexuses around them, and pass to the posterior pulmonary plexus (fig. 720).

(2) **Aortic branches,** some of which arise directly from the ganglia and some from the pulmonary branches, and unite with branches from the cardiac plexus and from the splanchnic nerves to surround the aorta as the **thoracic aortic plexus** (fig. 720). This plexus accompanies the aorta into the abdomen and there joins with the cœliac (solar) plexus.

(3) **Œsophageal branches** join with the œsophageal plexus of the vagus.

(4) **Vertebral branches,** some of which pass with the nutrient arteries into the bodies of the vertebræ and some of which pass to the median line and there anastomose with similar branches from the opposite side (commissural branches).

The peripheral branches forming the *lower series* consist largely of efferent fibres from the spinal nerves, which pass through the ganglia and reinforce the sympathetic filaments proper. Thus composed, these branches run ventralwards and inwards on the sides of the bodies of the vertebræ and unite to form the splanchnic nerves which supply the abdominal organs.

(1) The **great splanchnic nerve** may be formed by branches from all the thoracic ganglia from the fifth to the tenth inclusive, or it may receive fibres from only two or three of these ganglia (fig. 719). It is usually formed by branches from the fifth to the tenth. The superior branch, usually the largest, receives smaller inferior branches from the lower ganglia as it passes downwards on the sides of the bodies of the vertebræ in the posterior mediastinum. The nerve enters the abdominal cavity by passing through the crus of the diaphragm, and joins the upper end of the cœliac (semilunar) ganglion of the cœliac (solar) plexus. Near the bottom of the eleventh or the top of the twelfth thoracic vertebra there is formed on the nerve the **splanchnic ganglion.** Filaments from the nerve and from this ganglion pass along the intercostal arteries to the aorta, œsophagus, and the thoracic duct, and some fibres from the right side pass to the vena azygos (major). Sometimes this nerve divides into two cords, giving off numerous branches which anastomose with each other and with the small splanchnic nerve to form a plexus, in the meshes of which are found some small ganglia.

(2) The **lesser splanchnic nerve** receives fibres from the ninth and tenth ganglia. Its course is similar to that of the great splanchnic nerve (fig. 719), but on a posterior plane, and it terminates in the cœliac (solar) or renal plexuses.

(3) The **least splanchnic nerve,** not always present, arises from the last thoracic ganglion or sometimes from the small splanchnic nerve. It passes through the crus of the diaphragm and ends in the renal plexus.

Construction of the thoracic portion of the cord.—The majority of the sympathetic fibres which pass from the central nervous system enter the thoracic portion of the sympathetic trunk; some end there in ramifications around the cells of its ganglia, while others merely pass through on their way to more distant terminations. With regard to those which terminate in the ganglia, it has been shown that in the dog and cat many end in the ganglion stellatum, which corresponds with the last cervical and the upper three or four thoracic ganglia in man. Among these are the fibres conveying secretory impulses to the sweat-glands of the upper limb, which emerge from the spinal cord in the thoracic nerves from the sixth to the ninth, and, in the dog, vaso-constrictor fibres of the pulmonary blood-vessels which leave the spinal cord in the second to the seventh thoracic nerves. Other fibres which terminate around the thoracic sympathetic ganglion-cells in the dog and cat are the vaso-constrictor fibres for the upper limbs and some of the vaso-constrictor fibres for the lower limbs.

Of the fibres which traverse the thoracic portion of the sympathetic trunk to gain more distant terminations, some ascend to the cervical region (p. 1007), others descend

to the lumbar region, and many pass by the immediate peripheral branches to the splanchnic nerves.

Among those which descend to the lumbar region are pilo-motor fibres, vaso-motor fibres, and secretory fibres to the lower limb, some vaso-constrictor fibres to the abdominal blood-vessels, motor fibres to the circular, and inhibitory fibres to the longitudinal muscle of the rectum. The latter enter the sympathetic trunk by the lower thoracic nerves and pass in the lumbar peripheral branches to the aortic plexus, and terminate around the cells of the inferior mesenteric ganglion.

The fibres which pass through the thoracic ganglia to the splanchnic nerves are mainly vaso-motor fibres to the abdominal blood-vessels; the majority of them probably terminate around the cells of the ganglia in the cœliac (solar) plexus, but those for the renal blood-vessels no doubt end in the renal ganglia. In addition to all the above-mentioned fibres there are in the thoracic part of the sympathetic trunk afferent (splanchnic sensory) fibres of both sympathetic and cerebro-spinal type, passing towards the spinal ganglia and dorsal roots of the thoracic spinal nerves.

THE LUMBAR PORTION OF THE SYMPATHETIC TRUNK

The lumbar portion of each trunk lies on the fronts of the bodies of the vertebræ along the anterior border of the psoas muscle, and nearer to the median line than the thoracic portion. It is connected with the thoracic portion of the sympathetic trunk by a slender intermediate portion of the trunk that may pass through the diaphragm or behind it (fig. 719). The continuation of the lumbar into the sacral portion is also slender, and descends behind the common iliac artery. The right trunk is partly covered by the vena cava inferior and the left by the aorta.

The **ganglia,** which are small and oval, vary in number from three to eight, but are usually four. Rarely they are so fused as to form one continuous ganglion.

White rami communicantes pass to the ganglia from the first two or three lumbar nerves only. This portion of the trunk also receives efferent splanchnic fibres which are derived from the white rami communicantes of the lower thoracic nerves and continued downwards in the trunk.

Branches.—As in the thoracic region, the communicating branches are central and peripheral. The central are **grey rami communicantes.** There may be two branches to a nerve or one ramus may divide so as to join two adjacent spinal nerves. Sometimes a spinal nerve may receive as many as five grey rami from the sympathetic trunk.

The **peripheral branches** include:—(*a*) Branches passing to the aorta and taking part in the formation of the aortic plexus; (*b*) branches which descend in front of the common iliac artery to the hypogastric plexus; and (*c*) branches to the vertebræ and ligaments.

THE SACRAL PORTION OF THE SYMPATHETIC TRUNK

The sacral part of each trunk passes downwards in front of the sacrum, immediately outside the inner borders of the anterior sacral foramina. It is continuous above with the lumbar portion of the trunk, and below it anastomoses freely in front of the coccyx with the trunk of the other side to form a plexus in the terminus of which is the **coccygeal ganglion** (*ganglion coccygeum impar*) (fig. 719). Like the cervical and lower lumbar portions of the sympathetic trunk, the sacral part receives no white rami communicantes from the spinal nerves.

The sacral **ganglia** are small in size, and usually four in number. The variation both in size and number is more marked in this portion of the trunk than in the other two parts.

Branches.—The branches of the sacral ganglia include:—

(1) Grey rami communicantes to the sacral nerves.

(2) Branches to the front of the sacrum which anastomose with their fellows of the opposite side (commissural branches).

(3) Branches which enter into the formation of the plexus on the middle sacral artery.

(4) Branches which join the pelvic plexuses.

(5) Branches given off by the ganglion coccygeum impar to the coccyx and its ligaments and to the *glomus coccygeum* (coccygeal gland).

Construction of the lumbar and sacral portions of the sympathetic trunk.—The ganglia of both these portions of the trunk are very variable in shape, size, position, and number. There are usually four ganglia belonging to each portion, but sometimes as many as eight may be distinguished in the lumbar or there may be as many as six in the sacral portion. In the majority of cases, especially in the sacral region, these masses of cells are so fused that their number is less than the number of the spinal nerves with which they are associated. As noted above, only the first two or three lumbar spinal nerves send white rami which connect as such directly with these ganglia. However, splanchnic efferent fibres descend this entire stretch of the trunk, through both the lumbar and sacral portions, from the white rami of the lower thoracic and the upper lumbar nerves above. These fibres either terminate in the various ganglia or pass uninterrupted into the peripheral branches, and are concerned in the transmission of impulses which are vaso-motor to the genital organs, motor for the uterus, the vas deferens, and the circular coat of the bladder. Also, some of them convey secretory, pilo-motor, and vaso-motor impulses for the glands, skin, and vessels of the lower extremity in addition to the similar impulses conveyed in the peripheral branches from the lower part of the thoracic portion of the sympathetic trunk. The motor fibres for the uterus or vas deferens and for the bladder pass, in most part probably, by way of the peripheral branches from the lumbar portion of the cord, through the aortic plexus to the inferior mesenteric ganglion; others, the vaso-motor fibres to the genital organs especially, pass by way of the sacral ganglia and the peripheral branches from them to the hypogastric or pelvic plexus and the appropriate sub-plexuses of this region. Of the vaso-motor fibres for the penis, some of the constrictor fibres pass down the sacral portion of the sympathetic trunk and terminate about the cells of the sacral ganglia, and these cells send out sympathetic fibres which join and course in the pudic nerve (n. pudendus).

All of both the lumbar and sacral spinal nerves receive grey rami from the sympathetic trunk. These, just as those from the other portions of the trunk, consist of—(1) vaso-motor fibres to the meninges and vessels of the vertebral canal; (2) sympathetic fibres which join the divisions of the spinal nerves and course in them to their distribution, and (3) afferent sympathetic fibres terminating in the spinal ganglia.

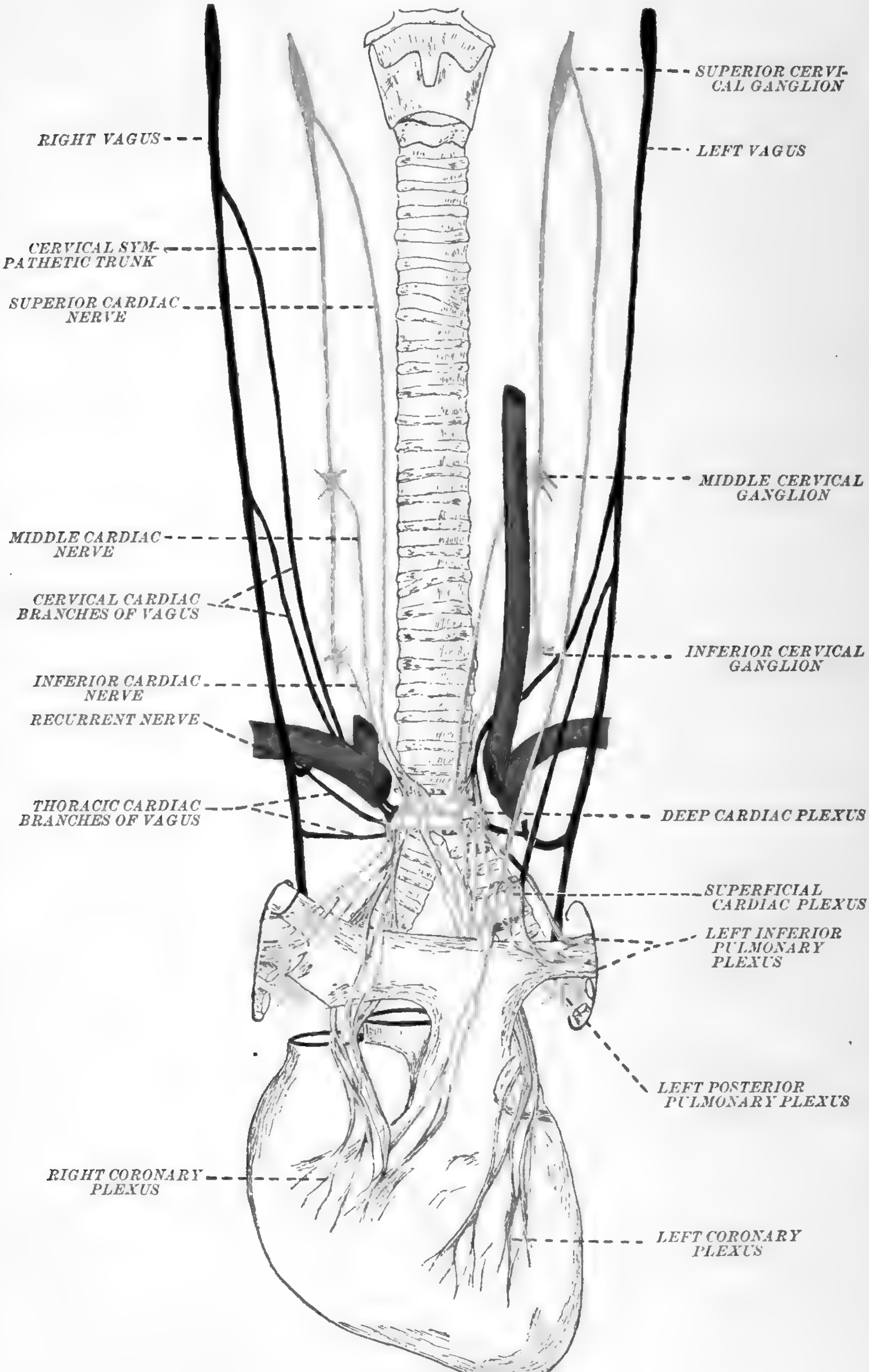
In addition to the efferent splanchnic fibres, the branches of the lumbo-sacral portion of the sympathetic trunk carry cerebro-spinal fibres of general sensibility—sensory fibres arising in the spinal ganglia of this and the lower thoracic region.

There are no white rami proper passing from the sacral spinal nerves to course or terminate in the sympathetic trunk. Efferent splanchnic fibres are given off by these nerves in abundance, but, instead of entering the trunk and its ganglia, they form bundles which pass over the trunk and directly into its peripheral branches. The bundles passing from the second, third, and fourth sacral nerves are large and especially definite. While homologous to white rami, such bundles are better known as the *visceral branches* of the sacral nerves or the **pelvic splanchnics.** They contain some cerebro-spinal sensory fibres (afferent splanchnic), but consist for the most part of efferent splanchnic fibres, conveying impulses, vaso-motor (vaso-dilator, chiefly) to the genital organs, both motor and inhibitory for the rectum, uterus, and bladder (longitudinal coat especially), and secretory for the prostate gland. These fibres contribute to the hypogastric plexus and are interrupted in the small ganglia of its sub-plexuses, named according to the various urino-genital organs concerned.

THE GREAT PREVERTEBRAL PLEXUSES

The great prevertebral plexuses are three in number,—the cardiac, the cœliac (solar or epigastric), and the hypogastric or pelvic. The cardiac plexus lies behind and below the arch of the aorta, and the cœliac and hypogastric plexuses are situated in front of the lumbar vertebræ. Each plexus receives not only sympathetic fibres which have passed from or through the ganglia of the sympathetic trunks of either side, but also both afferent and efferent cerebro-spinal nerve-fibres derived directly from the cerebro-spinal nerves. In addition the cardiac and cœliac plexuses receive both efferent splanchnic and cerebro-spinal sensory or afferent splanchnic fibres from both vagus nerves. It should be clearly understood that the branches which run from the sympathetic trunks to the prevertebral plexuses contain medullated

Fig. 720.—Cardiac, Pulmonary, and Coronary Plexuses. (Schematic.) (Modified from Cunningham.)



fibres which are passing, like the fibres from the sacral nerves, directly from the spinal cord to the cells of the plexuses.

The Cardiac Plexus

The cardiac plexus is formed by the cardiac branches from both vagus nerves and from both sympathetic trunks. It lies beneath and behind the arch of the aorta, in front of the bifurcation of the trachea, and extends a short distance upwards on the sides of the trachea. It is composed of a superficial and a deep part (fig. 720).

The **superficial part of the cardiac plexus** is much smaller than the deep part, and lies beneath the arch of the aorta in front of the right pulmonary artery. It is formed chiefly by the cardiac branches of the left vagus and by the left superior cardiac nerve, but sometimes receives filaments from the deep cardiac plexus. The **cardiac ganglion (ganglion of Wrisberg)**, usually found connected with this plexus, lies on the right side of the ligamentum arteriosum.

Branches.—From this plexus some connecting branches pass to the left half of the deep cardiac plexus, and others accompany the left pulmonary artery to the *left anterior pulmonary plexus*. It also sends branches to the *right anterior coronary plexus*.

The **deep portion of the cardiac plexus** lies behind the arch of the aorta at the sides of the lower part of the trachea and in front of its bifurcation. It consists of two lateral parts, more or less distinct, connected by numerous branches, which pass around the lower part of the trachea. It is formed by the superior, middle, and inferior cervical cardiac branches from the right sympathetic trunk, the middle and inferior cervical cardiac branches from the left trunk, and all the cervical and thoracic cardiac branches of the vagus nerves except the inferior cervical cardiac branch of the left vagus. It also receives branches from the superficial cardiac plexus.

The *left part of the deep cardiac plexus* gives branches to the left atrium (auricle) of the heart, to the left anterior pulmonary plexus, to the left coronary plexus, and sometimes to the superficial part of the cardiac plexus.

The *right part of the deep cardiac plexus* gives branches to the right atrium, to the right anterior pulmonary plexus, and to the right and the left coronary plexuses (fig. 720). The branches to the left coronary plexus pass behind the pulmonary artery. Some of those to the right coronary plexus pass anterior and some posterior to the right pulmonary artery.

The **coronary plexuses** are formed by branches given off by the cardiac plexus. They accompany the coronary arteries and are right and left.

The *anterior (right) coronary plexus* receives filaments from the superficial part of the cardiac plexus, but is formed chiefly by filaments from the right portion of the deep cardiac plexus (fig. 720). Its distribution to the heart follows that of the right coronary artery.

The *posterior (left) coronary plexus* is larger than the anterior plexus, and is formed for the most part by filaments from the left portion of the deep cardiac plexus, but it receives some filaments from the right portion of the deep cardiac plexus (fig. 720). Its distribution to the heart follows that of the left coronary artery.

The cardiac plexus and the network of nervous structures in the walls of the atria are the remains of the primitive plexuses found in the embryo, which are called the *bulbar*, the *intermediate*, and the *atrial* plexuses, terms which sufficiently indicate their relative positions. The bulbar plexus gives off the coronary nerves and is transformed into the superficial part of the deep cardiac plexus; the remainder of the deep cardiac plexus is formed by the intermediate plexus, and the atrial plexus becomes the network of the atrium.

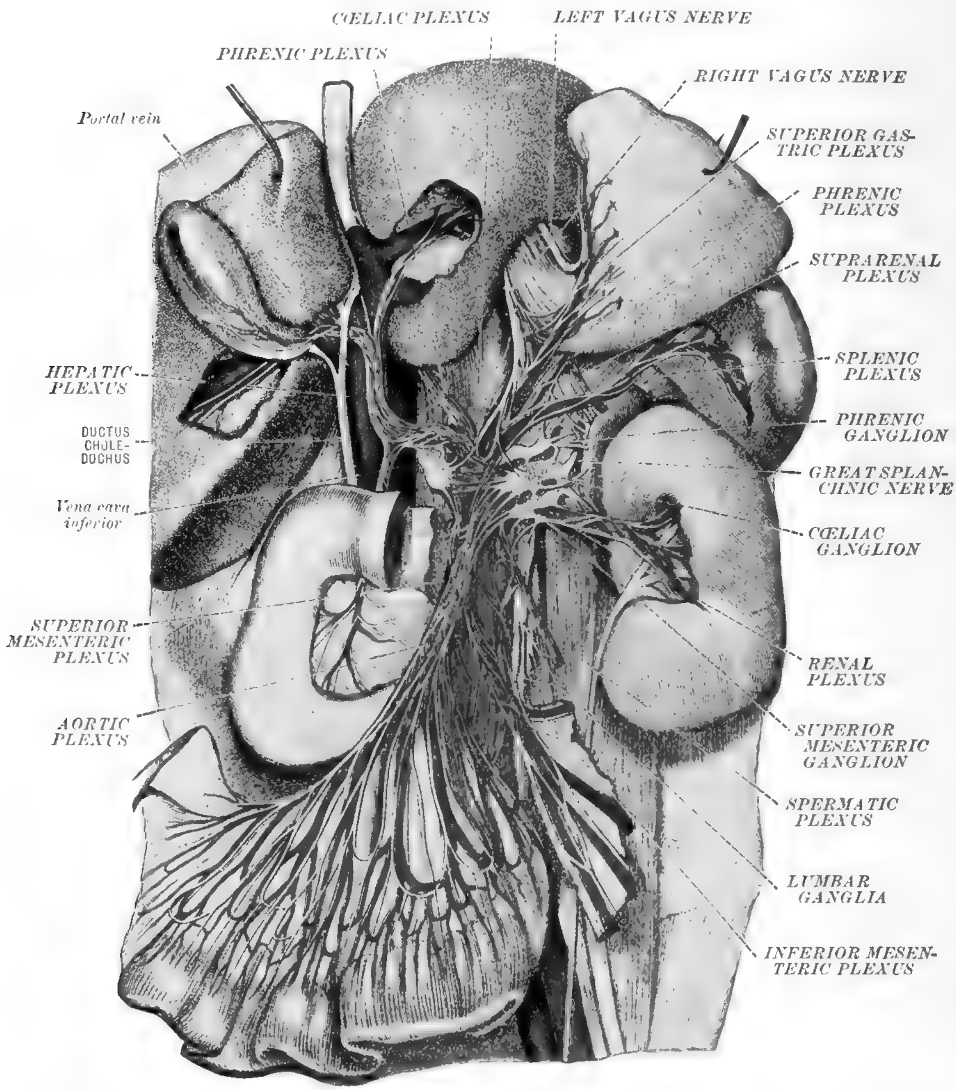
The fibres which pass to the cardiac plexus are medullated and non-medullated; the former are inhibitory, the latter motor. The inhibitory impulses leave the central nervous system by the spinal accessory and vagus nerves. The motor fibres leave the spinal cord by the ventral roots and white rami communicantes of the thoracic nerves and terminate about the cells of the intervening sympathetic ganglia. From the cells of these ganglia arise the non-medullated (grey) fibres of the plexus.

The Cœliac Plexus

The cœliac (solar or epigastric) plexus is the largest of the prevertebral plexuses. It is unpaired, and is continuous above with the aortic plexus of the thorax and below

with the abdominal aortic and superior mesenteric plexuses. It lies in the epigastric region of the abdomen behind the bursa omentalis (lesser sac of the peritoneum) and the pancreas, upon the crura of the diaphragm and over the abdominal aorta, and around the origin of the cœliac and the superior mesenteric arteries. It occupies the interval between the suprarenal bodies and extends downwards as far as the renal arteries. It is formed by the great and the lesser splanchnic nerves of both sides, by cœliac branches of the right vagus, and by filaments from the upper lumbar ganglia of

Fig. 721.—Abdominal Plexuses of the Sympathetic. (After Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



the sympathetic trunk. It sometimes receives cœliac branches from the left vagus. It contains two large ganglia, the right and left cœliac (semilunar) ganglia (fig. 721).

The **cœliac (semilunar) ganglia** are two large, flat, irregularly shaped masses, separable into a varying number of ganglia. These two masses, or rather the smaller ganglia which compose them, are connected by a varying number of communicating branches. Each mass, right and left, lies upon the corresponding crus of the diaphragm, at the inner border of the corresponding suprarenal body, being sometimes overlapped by this body. The right mass lies behind the inferior vena cava. Each cœliac ganglion receives at its upper border the greater splanchnic

nerve, and, near its lower border, lying over the origin of the renal artery, is a more or less detached part, known as the **aortico-renal ganglion.** This ganglion receives the lesser splanchnic nerve and may seemingly give origin to the greater part of the renal plexus. Another part of the cœliac ganglion, often found behind the origin of the superior mesenteric artery, is known as the **superior mesenteric ganglion** (fig. 721).

From the cœliac plexus and its ganglia subordinate plexuses are continued upon the aorta and its branches. These comprise both paired and unpaired plexuses. The paired plexuses are the phrenic, suprarenal and renal, the spermatic in the male, and, in the female, the ovarian plexuses. The unpaired plexuses are the aortic, hepatic, splenic, superior gastric, inferior gastric, superior mesenteric, and inferior mesenteric.

That part of the cœliac plexus surrounding the cœliac artery was formerly described as the *cœliac plexus.* It is better considered as an unnamed part of the larger cœliac plexus. This part of the plexus receives fibres from both vagus nerves, and gives filaments that form plexuses around the branches of the cœliac artery and their ramifications.

The paired subordinate plexuses:—(1) The **phrenic (diaphragmatic) plexuses** consist of fibres from the upper part of the cœliac ganglia, which follow the inferior phrenic arteries and their branches on the under surface of the diaphragm (fig. 721). Filaments are given off by the roots of the plexuses to the suprarenal bodies, and others unite with the terminal branches of the phrenic nerves. The point of junction with the right phrenic nerve is marked by the **phrenic ganglion,** from which branches are distributed to the inferior vena cava, to the right suprarenal body, and to the hepatic plexus.

(2) The **suprarenal plexuses** are comparatively large plexuses, formed mainly by branches from the cœliac (semilunar) ganglia. However, fibres come to them from the cœliac plexus along the suprarenal arteries, from the phrenic plexus along the inferior phrenic arteries, and from the renal plexus, along the inferior suprarenal arteries. They are distributed to the substance of the suprarenal bodies.

(3) The **renal plexuses** receive fibres from the lower part of the cœliac ganglia and from the cœliac and aortic plexuses. They also receive filaments from the least splanchnic nerves, when these nerves are present, and sometimes filaments from the small splanchnic nerves and from the first lumbar ganglion of the sympathetic trunk. These plexuses pass along the renal arteries into the substance of the kidneys. Most of the fibres of each renal plexus are grey fibres, and as they pass to the kidneys small *renal ganglia* are developed upon them. Both renal plexuses give branches to the corresponding spermatic plexuses and to the ureter, and the right renal plexus gives filaments also to the inferior vena cava.

(4 a) The **spermatic plexuses** (fig. 721) are formed by fibres from the renal and aortic plexuses. They accompany the spermatic arteries and are joined at the abdominal inguinal (internal abdominal) ring by fibres that have passed along the vas deferens from the pelvic plexuses. Their terminal filaments are distributed to the testis and the epididymis.

(4 b) The **ovarian plexuses** are formed in the female like the spermatic plexuses in the male. They accompany the ovarian arteries and, in the broad ligament, receive fibres from the utero-vaginal plexus. They supply the ovaries, the broad ligaments, and the Fallopian tubes, and send some fibres to the fundus of the uterus, where they become continuous with the utero-vaginal plexus.

The unpaired subordinate plexuses:—(1) The **abdominal aortic plexus** is formed by two strands of fibres which descend along the sides of the aorta and communicate with each other across its ventral aspect. It is connected above with the renal plexuses, and it receives peripheral branches from some of the lumbar ganglia of the sympathetic trunk on each side. It often contains a number of ganglia, which are situated at the points where the peripheral branches join the plexus, and it terminates below, chiefly by anastomoses with the hypogastric plexus (figs. 721 and 722). Besides giving filaments to the inferior vena cava, it also gives fibres that form plexuses along each of the branches of the aorta. The fibres that pass from the lower end of the aortic plexus upon the common iliac artery form the **iliac plexus,** which is continued along the femoral artery as the **femoral plexus,** and still further along the popliteal artery as the **popliteal plexus.**

(2) The **superior gastric (coronary) plexus,** receiving filaments from the

cœliac plexus, accompanies the left gastric (coronary) artery along the lesser curvature of the stomach. Its filaments anastomose with filaments of the vagus nerves and with the plexus that accompanies the right gastric (pyloric) artery (fig. 721), and it gives fibres to the walls of the stomach which connect, within the walls, with the delicate gangliated plexus myentericus and plexus submucosus (plexuses of Auerbach and Meissner).

(3) The **inferior gastric plexus** receives from the splenic plexus filaments that accompany the left gastro-epiploic artery. It gives filaments to the walls of the stomach, and communicates with filaments from the vagus nerves and with the plexus that accompanies the right gastro-epiploic artery.

(4) The **hepatic plexus** receives filaments from the cœliac plexus and from the left vagus. It accompanies the hepatic artery and gives fibres that form plexuses on the branches of the artery and on their ramifications within the liver. It also gives filaments to the portal vein (fig. 721).

The **splenic** or **lienal plexus** is formed by filaments from the cœliac plexus, the left cœliac (semilunar) ganglion, and from the right vagus. It accompanies the splenic artery and gives filaments which form plexuses on the branches of this artery, and which pass with the branches to supply fibres to the stomach and the pancreas (fig. 721).

(5) The **superior mesenteric plexus** is formed chiefly by filaments from the lower part of the cœliac plexus, but it also receives fibres from the right vagus and fibres direct from the cœliac (semilunar) ganglia. At the origin of this plexus, behind the superior mesenteric artery, lies the *superior mesenteric ganglion* (fig. 721). The filaments of the plexus, which are white and firm, accompany the superior mesenteric artery and, following its branches and their ramifications, are distributed to the walls of the small intestine, the cæcum, and the ascending and transverse colon. From the *secondary plexuses* that accompany the branches of the artery fibres pass to form still other plexuses that lie near the wall of the intestine, between the branches of the artery and between the layers of the mesentery. Filaments pass with the branches of the arteries and from plexuses between them into the intestinal wall, and there form between the longitudinal and circular muscle layers of the intestine the fine gangliated **plexus myentericus** (plexus of Auerbach), and filaments from this plexus form in the submucosa the delicate **plexus submucosus** or plexus of Meissner.

(6) The **inferior mesenteric plexus** is derived chiefly from the left side of the aortic plexus. It descends upon the inferior mesenteric artery and gives off filaments which accompany the branches of the artery and are distributed to the descending colon and to the ilio-pelvic colon (figs. 721 and 722). The filaments which accompany the left colic branch of the inferior mesenteric artery anastomose with the filaments of the superior mesenteric plexus which accompany the middle colic artery. The filaments which accompany the superior hæmorrhoidal artery form the **superior hæmorrhoidal plexus.** This plexus gives off the *superior hæmorrhoidal nerves* (fig. 722) which supply the upper part of the rectum and anastomose with the *middle hæmorrhoidal plexus.*

The Hypogastric Plexus

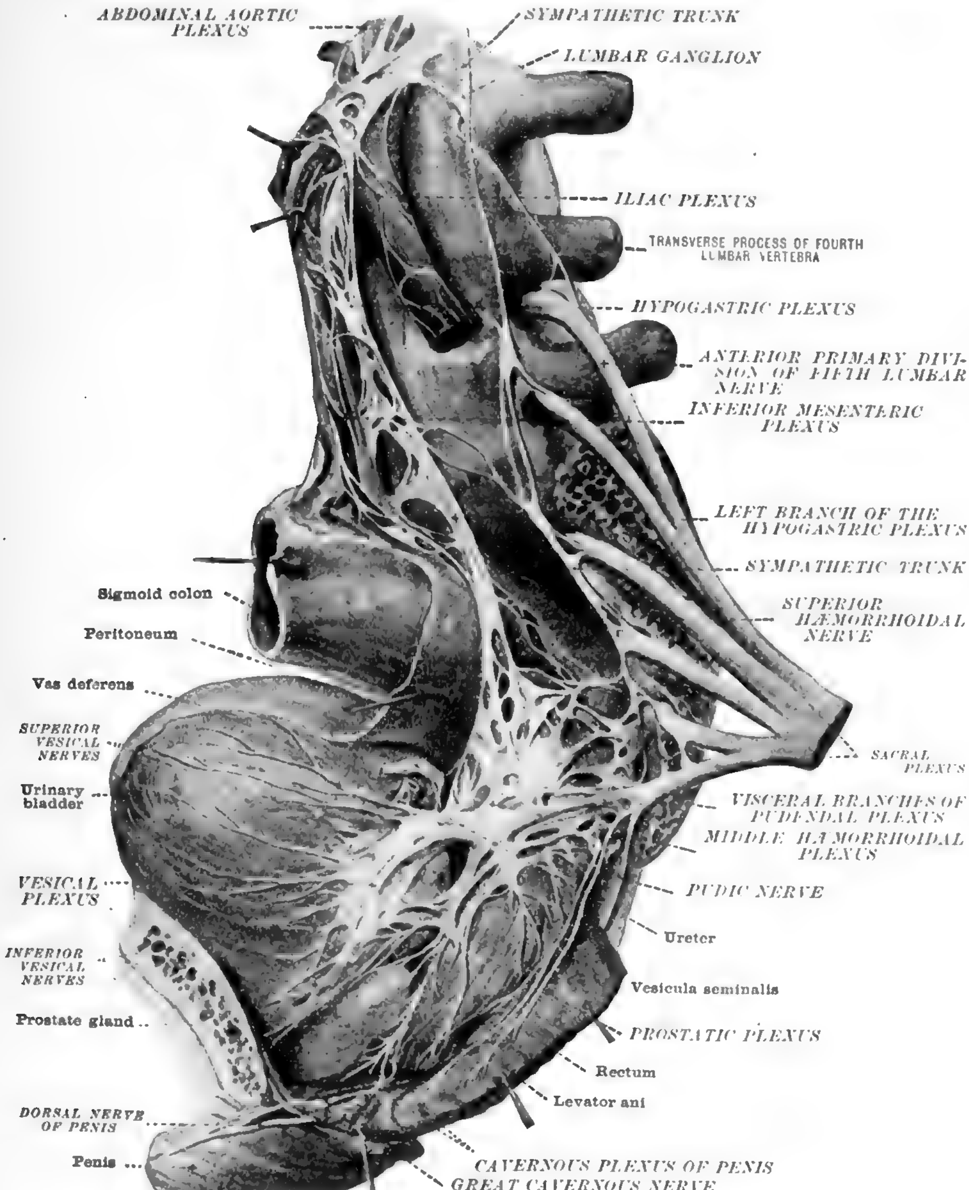
The hypogastric plexus lies partly in the abdominal cavity and partly in the pelvic cavity. It is formed chiefly by filaments continued downwards from the aortic plexus, and by the pelvic splanchnics and peripheral branches from the lumbo-sacral nerves and sympathetic trunk (fig. 716). The *abdominal part* of this plexus consists of plexiform bundles of fibres descending between the common iliac arteries and interlacing in front of the fifth lumbar vertebra to form a broad, flattened, plexiform mass. In its extent it receives branches from the lumbar ganglia of the sympathetic trunk. This plexiform mass then divides into two parts, right and left, which descend into the pelvic cavity and which, by English authors, are frequently designated as the *pelvic plexuses.*

The *pelvic parts* of the hypogastric plexus (pelvic plexuses) lie at the sides of the rectum in the male, and at the sides of the rectum and the vagina in the female. They receive peripheral branches from the sacral ganglia of the sympathetic trunk and efferent splanchnic fibres by way of the *pelvic splanchnics* from the second and third or third and fourth sacral spinal nerves. Each pelvic part of the plexus accom-

panies the corresponding hypogastric (internal iliac) artery, and gives off secondary plexuses that continue on the branches of the artery to the pelvic viscera. Of these secondary plexuses, the middle hæmorrhoidal and the vesical plexus are common to both sexes and are paired.

The **middle hæmorrhoidal plexus** passes on each side along the middle hæmorrhoidal artery to the rectum, where it receives the superior hæmorrhoidal nerves and sends filaments into the wall of the rectum (fig. 722).

FIG. 722.—THE HYPOGASTRIC AND SUB-PLEXUSES OF THE PELVIC CAVITY. (After Spalteholz.)



The **vesical plexus** receives some branches from the pelvic parts of the hypogastric plexus, but is largely reinforced by the pelvic splanchnics, from the third and fourth sacral nerves. Each part passes along the corresponding vesical arteries to the bladder, and gives off two sets of branches, namely, the *superior vesical nerves* (fig. 722), which supply the upper part of the bladder-wall and send some branches to the ureter,

and the *inferior vesical nerves,* which supply the lower part of the bladder and, in the male, give secondary **deferential plexuses** to the vas deferens. These plexuses surround the vasa deferentia and the vesiculæ seminales and anastomose with the spermatic plexuses.

The **prostatic plexus,** found only in the male, is formed in two parts by nerves of considerable size, and lies chiefly on the sides of the prostate gland between it and the levator ani (fig. 722). Each of these parts supplies the gland and the prostatic part of the urethra, and sends offsets to the neck of the bladder and the vesiculæ seminales. This plexus is continued forwards on either side to form the **cavernous plexus of the penis** (fig. 722), which anastomoses with branches of the dorsal nerve of the penis, gives off branches to the membranous part of the urethra, and also gives origin to two sets of nerves, namely, the large and the small cavernous nerves of the penis.

The **large cavernous nerve,** one on each side, runs forwards to the middle of the dorsum of the penis, where it anastomoses with the dorsal nerve of the penis on the corresponding side, and ends in twigs which are distributed chiefly to the corpus cavernosum penis, but some of the terminal filaments supply the corpus cavernosum urethræ (corpus spongiosum) (fig. 722).

The **small cavernous** nerves are small filaments which pierce the uro-genital trigone (triangular ligament) and the compressor urethræ, and enter the posterior part of the corpus cavernosum.

The **plexus utero-vaginalis,** found in the female, is formed in its *upper part* on each side largely by fibres derived from the pelvic part of the hypogastric plexus, but it receives some fibres from the pelvic splanchnics of the third and fourth sacral nerves. The nerves from this part of the plexus accompany the uterine arteries as they pass between the layers of the broad ligament. Some accompany each uterine artery and its branches to their termination, but a considerable number of fibres leave the artery and pass into the body of the uterus to supply its lower part and cervix. Between the layers of the broad ligament this plexus anastomoses with the ovarian plexus and sends some filaments to the tuba uterina (Fallopian tube). The *lower part* of the plexus utero-vaginalis receives some fibres on each side from the pelvic part of the hypogastric plexus, but it is formed chiefly by efferent splanchnic fibres from the second, third, and fourth sacral nerves. It supplies the wall and mucous membrane of the vagina and urethra. From the plexus on the anterior surface of the vagina fibres pass to form the **cavernous plexus of the clitoris,** which gives off the great and lesser **cavernous nerves of the clitoris** for the supply of the clitoris. The utero-vaginal plexus of the female corresponds to the prostatic plexus of the male.

SECTION VII

ORGANS OF SPECIAL SENSE

THE EYE

By R. MARCUS GUNN, M.A., F.R.C.S.,

SENIOR SURGEON TO THE ROYAL LONDON OPHTHALMIC HOSPITAL, MOORFIELDS; OPHTHALMIC SURGEON TO THE NATIONAL HOSPITAL

THE EYEBALL AND ITS SURROUNDINGS

General Surface View

This examination is to be made prior to any disturbance of the parts, and is, indeed, best conducted on the living body. A pocket magnifying lens should be at hand for use when required.

THE two eyes are situated nearly in the line where the upper and middle thirds of the face meet; they lie right and left of the root of the nose, the most prominent part of the front of each globe being about 3 cm. (1¼ in.) from the middle line of the face. Each eye is overshadowed by the corresponding eyebrow, and is capable of being concealed by its eyelids, upper and lower.

The orbital margin may be traced all round with the finger. At the junction of the inner and middle thirds of the upper margin the supraorbital notch can usually be felt, and the supraorbital nerve passing through it can sometimes be made to roll from side to side under the finger. The inner margin is the most difficult to trace in this way, partly because it is more rounded off than the others, partly because it is bridged over by a firm fibrous band **(tendo oculi,** or **inner palpebral ligament),** passing inwards from the eyelids; below this band, however, a sharp bony crest is felt, which lies in front of the lachrymal sac. Note how the eye is protected by the rim of the orbit, above and below; if we lay a hard flat body over the orbital opening, it will rest upon the upper and lower bony prominences, and will not touch the surface of the globe. Inwards, the eye is protected from injury mainly by the bridge of the nose; outwards it is most readily vulnerable, as here the orbital rim is comparatively low. With one finger placed over the closed upper lid, now press the eyeball gently backwards into the orbit, and observe the elastic resistance met with, due to the fact that the globe rests posteriorly on a pad of fat.

The space between the free edges of the upper and lower lids is known as the **palpebral aperture:** it is a mere slit when the lids are closed; but when they are open its shape is, roughly, that of an almond lying with its long axis horizontal, and about thirty millimetres in length.

When the eyes are directed to an object straight in front of them, this aperture is about twelve millimetres wide, but its width varies with upward and downward movements of the eyeball, being greatest on looking strongly upwards, diminishing gradually as the eye looks progressively lower. The angles formed by the meeting of the lids at each end of the palpebral aperture are named respectively the **outer** and **inner canthus,** of which the outer, or temporal, is sharp, while the inner, or nasal, is rounded off. On a closer inspection, it will be found that, for the last five millimetres or so before reaching the inner canthus, the edges of the lids run an almost

parallel course, and are here devoid of lashes. Through the open palpebral aperture the front of the eyeball comes into view, extending quite to the outer, but not reaching as far as the inner, canthus; just within the latter we find a small reddish prominence, the **lachrymal caruncle;** and between this and the eyeball a fold of conjunctiva known as the **plica semilunaris.** While the eye is open, press one finger on the skin, a little beyond the outer canthus, and draw it firmly outwards from the middle line; observe that the upper lid then falls over the eyeball, and that the outline of a firm band already referred to (the tendo oculi) becomes evident, passing between the inner canthus and the nose. The falling of the lid is caused by our dragging upon a ligament (the outer palpebral raphé) to which the outer end of its tarsus is attached, and so putting the lid itself upon the stretch. If, while the eyeball is directed downwards, we place one finger on the outer end of the upper eyelid and draw it forcibly upwards and outwards, we can usually cause the lower division of the lachrymal gland to present just above the outer canthus.

The **upper eyelid** is much broader than the lower, extending upwards as far as the eyebrow. The skin covering it is loosely attached to the subjacent tissues above, but more firmly below, nearer the free margin, where it overlies a firm fibrous tissue called the **tarsus.** When the eye is open, a fold is present at the upper border of this latter more tightly applied portion of skin, called the **superior palpebral fold,** and by it the lid is marked off into an upper or orbital, and a lower or tarsal, division. The presence of the tarsus can be readily appreciated on our pinching horizontally the entire thickness of the eyelid below the palpebral fold. The **lower eyelid** is similarly divided anatomically into a tarsal and an orbital part, but the demarcation is sometimes unrecognisable on the surface, though there is usually here also a fold or groove (the **inferior palpebral**) visible when the eye is widely opened. There is no precise limit of this lid below, but it may be regarded as extending to the level of the lower margin of the orbit. Numerous very fine short hairs are seen on the cutaneous surface of both eyelids. The free margin of each lid has two edges—(*a*) An outer, or anterior, rounded edge, along which the stiff eyelashes, or cilia, are closely placed in several rows; and (*b*) a sharp posterior edge, which is applied to the surface of the globe (see fig. 743). The lashes of both eyelids have their points turned away from the palpebral aperture, so that the upper ones curve upwards, and the lower downwards; the cilia of the upper lid are the stronger, and those in the middle of each row are longer than those at each end. Between the two edges just described, the lid-margin has a smooth surface, on which we observe a single row of minute apertures, which are the openings of large modified sebaceous glands (the **tarsal** or **Meibomian glands**); it is by these glistening, well-lubricated surfaces that the opposite lids come into apposition when they are closed. The sharp posterior edge of the lid-margin marks the situation of the transition of skin into mucous membrane. Not far from the inner end of this edge we find a prominence, the **lachrymal papilla,** on the summit of which is a small hole (**lachrymal punctum**), the opening of the canaliculus for the passage of tears into the lachrymal sac. The lower punctum is rather larger than the upper, and is placed further from the inner canthus.

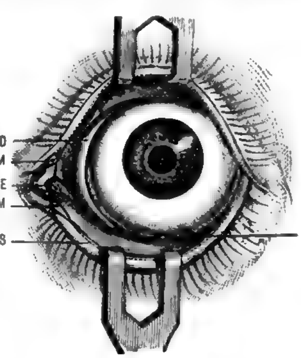
If we now examine the inner surface of the eyelids—e. g., of the lower—we observe that it is lined by a soft mucous membrane, the **palpebral conjunctiva.** Over the tarsal part of the lid the conjunctiva is closely adherent, but beyond this it is freely movable along with the loose submucous tissue here present. On tracing it backwards, we find that it covers the whole inner surface of the lids, and is then continued *forwards* over the front of the eyeball, forming the ocular conjunctiva; the bend it makes as it changes its direction here is called the conjunctival *cul-de-sac*, or **fornix.** Numerous underlying blood-vessels are visible through the palpebral conjunctiva, and beneath the tarsal part of it we can see a series of nearly straight, parallel, light yellow lines, arranged perpendicularly to the free margin of the lid—the tarsal glands. The conjunctiva over the outer and inner fourths of each lid is not quite so smooth as elsewhere, and is normally of a deeper red colour; we shall find later that there are glands well developed in these positions.

When the eyelids are opened naturally, we see through the palpebral aperture the following: the greater part of the transparent cornea, and behind it the coloured iris with the pupil in its centre; white sclerotic to the outer and inner sides of the cornea; the semilunar fold and lachrymal caruncle at the inner canthus. The extent of the eyeball visible in this way varies according to its position. Thus,

with the eyes looking straight forwards, the lower margin of the upper lid is nearly opposite to the top of the cornea, or, more strictly, to a line midway between the top of the cornea and the upper border of the pupil, while the lower lid corresponds with the lower corneal margin. When the eyes are directed strongly upwards, the upper lid is relatively on a slightly higher level, as it is simultaneously raised, but the lower lid now leaves a strip of sclerotic exposed below the cornea. On looking downwards the upper lid covers the upper part of the cornea as low down as the level of the top of the pupil, while the lower lid is about midway between the pupil and the lower corneal border.

If we draw the eyelids forcibly apart, we expose the whole cornea, and a zone of sclerotic about eight and a half millimetres in breadth above and below, and ten millimetres in breadth to the outer and inner sides—altogether about one-third of the globe; all the eyeball thus exposed is covered by the **ocular conjunctiva.** Over the sclerotic the conjunctiva is freely movable, and through it we see superficial blood-vessels that can be made to slip from side to side along with it (conjunctival vessels). Occasionally other deeper vessels may also be seen which do not move with the conjunctiva, but are attached to the sclerotic (anterior ciliary arteries and veins). Near the corneal border the conjunctiva ceases to be freely movable, and it is closely adherent to the whole anterior surface of the cornea, giving the latter its characteristic bright, reflecting appearance; no blood-vessels are visible through it here in health. (When the lids are shut, the space enclosed between their pos-

FIG. 723.—VIEW OF EYEBALL, ETC., OBTAINED ON DRAWING THE LIDS FORCIBLY APART. (After Merkel, slightly modified.)



terior surfaces and the front of the eyeball is thus everywhere covered by conjunctiva, and is known as the **conjunctival sac.**)

Not unfrequently the tendinous insertions of some or all of the recti muscles into the sclerotic may be seen through the conjunctiva, each insertion appearing as a series of whitish parallel lines running towards, but terminating about seven millimetres from, the corresponding corneal border. The cornea appears as a transparent dome, having a curvature greater than that of the sclerotic; the junction of the two unequally curved surfaces is marked by a shallow depression running around the cornea, known as the **scleral sulcus.** In outline the cornea is nearly circular, but its horizontal diameter is slightly greater than its vertical. Between it and the iris a space exists, whose depth we can estimate roughly by looking at the eye from one side; this space, or anterior chamber, is occupied by a clear fluid, the aqueous humour. Almost the whole anterior surface of the iris is visible, its extreme periphery only being concealed by sclerotic. In colour the iris varies greatly in different individuals. Near its centre (really a little up and in) a round hole exists in the iris, the black *pupil,* whose size varies considerably in different eyes, and in the same eye according to temporary conditions, such as exposure to light, etc.

In examining the surface-markings of the living iris, one of dark colour is to be preferred. Focal illumination will be found useful, for which purpose a second convex lens will be required.

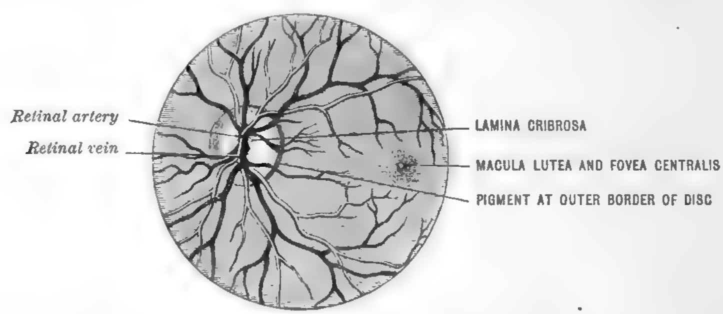
On the surface of the iris we see a number of ridges running more or less radially; adjoining ones occasionally unite and interlace to some extent, so as to leave large

depressed meshes at intervals. The radial ridges coming from the edge of the pupil, and those coming from the more peripheral part of the iris, meet in a zigzag elevated ridge concentric with the pupil, called the *corona iridis*, and by this ridge the iris is roughly marked off into two unequal zones—an outer, the **greater** or **ciliary,** and an inner, the **lesser** or **pupillary**—of which the inner is much the narrower. The border next the pupil is edged with small, roundish, bead-like prominences of a dark brown colour, separated from one another by depressions, so that it presents a finely notched contour. Not infrequently, in a light-coloured iris, we may see the sphincter muscle through the anterior layers, in the form of a ring about one millimetre in breadth around the pupil. The ciliary zone may be described as consisting of three parts:—(*a*) A comparatively smooth zone next the zigzag ridge; (*b*) a middle area, showing concentric but incompletely circular furrows; (*c*) a small peripheral darker part, presenting a sieve-like appearance. On the floor of the large depressed meshes, or *crypts*, parallel radial vessels can be traced, belonging to the iris-stroma. The zigzag line mentioned above corresponds to the position of the circulus arteriosus minor. Occasionally, especially in a light iris, superficial pigment spots of a rusty brown colour occur.

If we are examining the living eye, the ophthalmoscope should now be used, so as to gain a view of the fundus. We can thus study the termination of the optic nerve, the distribution of the larger retinal vessels, etc.

The general red reflex obtained from the fundus is due to the blood in a capillary network (**chorio-capillaris**) situated in the inner part of the chorioid. To

Fig. 724.—Left Fundus Oculi, as seen by direct Ophthalmoscopic Method.



the nasal side of the centre of the fundus is a paler area of a disc shape corresponding to the intraocular end of the optic nerve, and known as the **papilla of the optic nerve** or **optic disc.** This optic disc is nearly circular, but usually slightly oval vertically; it is of a light orange-pink colour, with a characteristic superficial translucency; its outer third segment is paler than the rest from the nerve-fibres and capillaries here being fewer. About its centre we often observe a well-marked whitish depression or gap, formed by the dispersion of the nerve-fibres as they spread out over the fundus; at the bottom of this depression a sieve-like appearance may be seen, due to the presence of the **lamina cribrosa,** which consists of a white fibrous tissue framework, with small, roundish, light-grey meshes in it, through which latter the nerve-fibre bundles pass. Also near the centre of the disc, the retinal blood-vessels first come into view, the arteries narrower in size and lighter in colour than the veins; they divide dichotomously as they are distributed over the fundus. The retina proper is so transparent as to be ophthalmoscopically invisible, but its pigment-epithelium gives a very finely granular or darkly stippled appearance to the general red reflex. In the centre of the fundus, and therefore to the outer side of the disc, the ophthalmoscope often shows a shifting halo of light playing round a horizontally oval, comparatively dark enclosed area; this latter corresponds to the **yellow spot** region, and about its centre a small pale spot usually marks the position of the **fovea centralis.**

Two structures visible at the nasal end of the palpebral aperture have been previously mentioned, and should now be examined more narrowly. The **lachry-**

mal caruncle is in reality an island of modified skin, and fine hairs can commonly be detected on its surface. On its outer side, separated from it by a narrow groove, is the **semilunar fold of conjunctiva;** it rests on the eyeball, and is a rudiment of the third eyelid or nictitating membrane, present in birds and well represented in many other vertebrates.

Examination of the Eyeball

The eyeball of a cadaver should now be removed by snipping with scissors the conjunctiva near the corneal border, then cutting through the ocular muscles near their insertion into the globe, and finally dividing the optic nerve close to the sclerotic.

The eyeball is almost spherical, but not perfectly so, mainly because its anterior, clear, or *corneal* segment has a greater curvature than the rest of the eye. Considering it as a globe, however, we speak of an **anterior** and of a **posterior pole;** the former corresponding to the middle of the front of the cornea, the latter to the middle of the posterior curvature. An imaginary straight line joining the two poles is called the antero-posterior or **sagittal axis** of the eyeball. The **equator** of the eye is that part of its surface which lies midway between the two poles. The sagittal axis of the globe is the greatest (about 24·5 mm.), the vertical equatorial the least (about 23·5 mm.), and the transverse equatorial axis is intermediate in length (about 23·9), so that the eyeball is in reality an ellipsoid, flattened slightly from above downwards. Again, if the globe is divided in its antero-posterior vertical plane, the nasal division will be found to be slightly smaller than the temporal. The optic nerve joins the globe three or four millimetres to the nasal side of the posterior pole.

The shape of the eye depends on, and is preserved by, the outermost tunic, formed conjointly by the cornea and sclerotic, the entire outer surfaces of which are now in view. The anterior or corneal part has been already examined. All around the cornea there remains a little adherent conjunctiva; elsewhere, the sclerotic is directly exposed, except for some loose connective tissue which adheres to it, especially around the optic nerve entrance. In front of the equator we see the tendinous insertions of the four recti muscles. Behind the equator are the insertions of the two oblique muscles—that of the superior oblique tendinous, and further forwards; that of the inferior more fleshy, and placed between the optic nerve and the external rectus.

It is difficult to recognise the different recti muscles by their insertions if we do not know whether the eye examined is a right or a left one. To determine this we should hold the globe with the optic nerve towards us, and in the natural position with the superior oblique tendon uppermost. The inferior oblique tendon will now point to the side to which the eye belongs, and we can consequently determine the different recti muscles.

The internal rectus is inserted nearest (7 mm. from) the corneal border; the external rectus commonly, sometimes the superior, is inserted furthest from it (about 8 mm.). All the recti tendons are broad and thin, but that of the internal is the broadest (8 mm.); those of the external and inferior the narrowest (6 mm.). The greatest interval between two neighbouring tendons is that between the superior and internal recti (about 12 mm.); the least is between the superior and external (7 mm.). The form of the lines of insertion of the different tendons varies considerably, the inferior being almost straight, the superior and external convex forwards, the internal further removed from the corneal border below than above.

The insertions of the obliques are at more than double the average distance of the insertions of the recti from the corneal border. That of the superior oblique is found on the superior surface of the sclerotic, about sixteen millimetres from the corneal edge, in the form of a line sloping from before backwards and inwards. The inferior oblique has a long fleshy insertion lying between the external rectus and the optic nerve entrance; the posterior end of the insertion, which is also the higher, is only about six millimetres from the optic nerve, and from this point it slopes forwards, outwards, and slightly downwards.

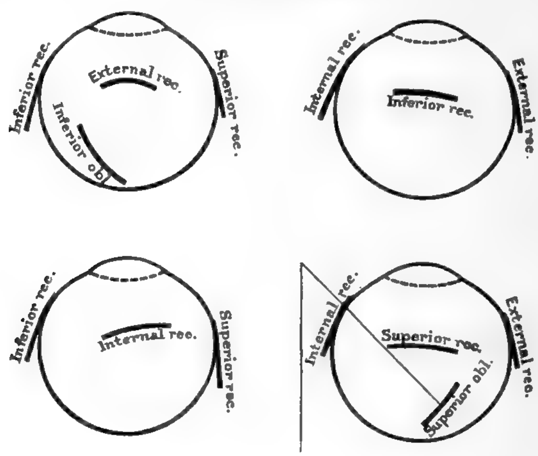
Several small nerves and two arteries may be seen running forwards and ultimately perforating the sclerotic not far from the entrance of the optic nerve. The two arteries are the long posterior ciliary; they both perforate the globe in the horizontal meridian, one on the outer, the other on the inner, side. The short ciliary

arteries are too small to be seen in an ordinary examination. The nerves are the long and short ciliary. Nearer the equator, the large venous trunks emerge; they can be traced for some distance in front of their exit as dark lines, running antero-posteriorly beneath the sclerotic. The optic nerve is seen in section, surrounded loosely by a thick outer sheath; in the centre of the nerve-section a small red spot indicates the position of the central retinal blood-vessels.

For ordinary dissections eyes of the sheep, pig, or bullock should be obtained. Divide an eyeball into fore and hind halves by cutting through it in the equatorial plane.

1. **Posterior hemisphere** seen from in front.—This is much the same view that the ophthalmoscope affords us. Unless the eye be very fresh, however, the **retina** will have lost its transparency, and will now present the appearance of a thin whitish membrane, detached in folds from the underlying coats, but still adherent at the optic disc. The vitreous jelly lying within the retinal cup may be torn away. In the human eye the retina next the posterior pole is stained yellow (**macula lutea**). On turning the retina over, a little pigment may be seen adhering to its outer surface here and there. Cut through the retina close to the optic disc all around and remove it: note how easily it is torn. We now see a dark brown surface, consisting of the **retinal pigment layer,** adherent to the inner surface of the chorioid. Brush off the retinal pigment under water. The **chorioid** thus exposed can for the most part be fairly easily torn away from the thick sclerotic, as a lymph-space exists between them, but the attachment is firm around the optic nerve entrance, and also where the arteries and nerves join the chorioid after penetrating the sclerotic. The chorioid is darkly pigmented, of a brown colour, with markings on its surfaces corresponding to the distribution of its large veins. The inner surface of the sclerotic is of a light brownish colour, mainly from the presence of a delicate pigmented layer, the **mem-**

Fig. 725.—Diagrammatic View of the Insertions of the Ocular Muscles. (After Merkel.)



brana suprachorioidea, which adheres partly to it, partly to the chorioid, giving to their adjacent surfaces a flocculent appearance when examined under water.

2. **Anterior hemisphere** viewed from behind.—The round opening of the pupil is visible in the middle, with the large clear **crystalline lens** lying nearer us. The retina proper extends forwards a little way from our line of section, and then ends abruptly in a wavy line called the **ora serrata,** beyond which it is only represented by a very thin membrane (**pars ciliaris retinæ**). Outside the periphery of the lens are a number of **ciliary processes** arranged closely together in a circle concentric with the pupil, and each radially elongated; posteriorly they are continuous with numerous fine folds, also radial, which soon get very indistinct as they pass backwards, but reach almost to the ora serrata (**plicæ ciliares**). Between the front of the ciliary processes and the edge of the pupil lies the **iris.** On removal of the retina the inner surface of all this region is seen to be darkly pigmented, but especially dark in front of the position of the ora serrata. Vitreous probably still adheres to the back of the lens, and by pulling upon it the lens can be removed along with its capsule and suspensory ligament; some pigment will now be found adhering to the front of the vitreous, torn from the ciliary processes, which are consequently now lighter in colour than before. The **lens-capsule** is transparent, and has a smooth glistening outer surface; through it a greyish, star-shaped figure may be observed on the anterior and posterior surfaces of the lens. The **suspensory ligament** is a transparent membrane attached to the capsule of the lens about its equator, and is best seen by floating the lens in water in a glass vessel placed on a dark ground. On opening the capsule we expose the lens itself, which is superficially soft and glutinous to the touch, but becomes firmer as we rub off its outer layers and approach its centre. Carefully tear the chorioid and iris from the sclerotic as far as possible; a firm adhesion exists just behind the corneal periphery. The outer surface of the chorioid thus exposed is found to be also rather darkly pigmented, but it shows a white ring corresponding to the adhesion just mentioned, and a pale area behind this ring indicates the position of

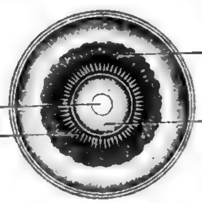
the ciliary muscle. On this surface numerous white nerve-cords are visible running forwards. Observe that the iris, the ciliary processes, etc., and the chorioid are all different parts of the same ocular tunic—mere local modifications of it. Similarly the sclerotic and cornea are seen to blend together to form one outer coat.

An eyeball should now be placed for half an hour in a freezing mixture of crushed ice and salt. It will thus become quite hard, and should at once be divided into two parts by cutting it antero-posteriorly through the centre of the cornea and the optic nerve. We thus gain another view of the relations of parts, the position of the lens between the aqueous and vitreous chambers, etc. On removing the lens, vitreous, and retina, and brushing off its pigment, the light markings corresponding to the chorioidal veins (**venæ vorticosæ**) should be noted, and their distribution studied. Usually four vortices or fountain-like markings are found in the whole chorioid, their points of junction situated at approximately equal distances from one another at about the line where the posterior and middle thirds of the globe meet. These sections should be kept for reference while following the further description of the ocular tunics.

1. The **outer, fibrous coat of the eye** is formed by the sclerotic and cornea, which pass into one another at the scleral sulcus. It consists throughout mainly of fine connective-tissue fibres, arranged in interlacing bundles, with small lymph-spaces at intervals between them. The naked-eye appearance of the two divisions of this fibrous coat is, however, quite different, the cornea being transparent, while the sclerotic is white and opaque.

The **sclerotic** encloses the posterior five-sixths or so of the eyeball, but there is a hole in it at the entrance of the optic nerve (**foramen scleræ**), only partially bridged across by fibres from its inner layers forming the **lamina cribrosa.** The fibre-bundles composing the sclerotic are arranged more irregularly than in the cornea, and run mainly in two directions, viz., from before backwards, and circularly; the circular fibres are particularly well developed just behind the sulcus. It is thickest (about 1 mm.) posteriorly, where it is strengthened chiefly by the outer

Fig. 726.—Equatorial Section of Eyeball: Anterior Segment viewed from behind. (After Merkel.)



sheath of the optic nerve, and partly also by the tissue surrounding the ciliary vessels and nerves. It becomes gradually thinner as it passes forwards, up to the line of insertion of the recti muscles, in front of which line it is again reinforced by their tendinous fibres becoming incorporated with it. In children the sclerotic is often so thin as to allow the underlying chorioidal pigment to show through, appearing then of a bluish white. In the aged, again, it is sometimes yellowish. It always contains a few pigment cells, but these are in the deep layer (lamina fusca), and only become visible externally where the sclerotic is pierced by vessels and nerves going to the chorioid. It is itself almost non-vascular, but quite at its anterior end a large **venous sinus (canal of Schlemm)** runs in its deeper layers circularly around the cornea. Just in front of this sinus, at the corneal **limbus,** the sclerotic merges into the cornea, its deep layers changing first, and finally the superficial ones.

The **cornea** is thickest at its periphery, and becomes gradually thinner towards its centre; the curvature of its posterior is consequently greater than that of its anterior surface, but even the latter is more curved than the surface of the sclerotic. In the cornea proper, fibre-bundles are arranged so as to form a series of superposed lamellæ, each of which is connected here and there to the adjacent ones by fibres passing from one to the other, so that they can only be torn apart with difficulty. The corneal lymph-spaces communicate with one another by very fine canals, and thus not only is a thorough lymph-circulation provided for, but the protoplasm with which these spaces are partially occupied may be also regarded as continuous throughout. It contains no blood-vessels, with the exception of a rich plexus at its extreme periphery, on which its nutrition is ultimately dependent.

The most superficial part of the true cornea appears homogeneous, even when highly magnified (**anterior elastic lamina, Bowman's membrane**), though there is reason to believe that its structure only differs from that already described in the closeness of its fibrous texture; the two parts are certainly connected by fine fibres. Anteriorly, the cornea is covered by an extension of the ocular conjunctiva, in the form of an epithelium several layers deep. Posteriorly, the cornea is lined by a firm, thin, glass-like layer (**posterior elastic lamina, membrane of Descemet**), distinct from the corneal tissue both anatomically and chemically. At the periphery this membrane breaks up into a number of fibres, which mainly arch over to join the base of the iris (**ligamentum pectinatum iridis**). The interstices between these fibres constitute spaces (**spaces of Fontana**) freely communicating with the aqueous chamber on the one hand, and indirectly with the canal of Schlemm on the other. Descemet's membrane is in turn lined by a single layer of flat cells, which are continuous peripherally with cells lining the spaces of Fontana and the anterior surface of the iris. The cornea is richly supplied with nerves, particularly in its most superficial layers.

2. The dark, **middle,** or **vascular coat of the eye,** generally known as the **uveal tract,** is formed by the iris, ciliary body, and chorioid. It is closely applied to the sclerotic, but actually joins it only at the anterior and posterior limits of their course together, viz., at the scleral sulcus, and around the optic nerve entrance. In front of the sulcus the middle coat no longer lines the outer, being separated from it (i. e., the iris from the cornea) by a considerable space filled with fluid, called the anterior aqueous chamber. The uveal tract has two openings in it; a larger one in front, the pupil, and a smaller one behind, for the passage of the optic nerve. Its structure is that of a pigmented connective tissue, supporting numerous blood-vessels and containing many nerves and three deposits of smooth muscle-fibres.

The **chorioid** forms the posterior part of the uveal tract, and extends, with slowly diminishing thickness, forwards as far as the ora serrata. Its outer and inner surfaces are both formed by non-vascular layers; that covering the outer, the **membrana suprachorioidea,** is pigmented, arranged in several fine loose lamellæ, and has been seen in our dissection; that covering the inner surface is a thin, transparent, homogeneous membrane, called the **basal** or **vitreous lamina** of the chorioid, or the **membrane of Bruch.** The intervening chorioidal stroma is very rich in blood-vessels, which are of largest size next its outer surface, and become progressively smaller as we approach the vitreous lamina, next to which we find a layer of closely placed wide capillaries, called the **lamina chorio-capillaris.** The pigment becomes less in amount as we pass inwards, and finally ceases, being absent entirely from the chorio-capillary and vitreous laminæ.

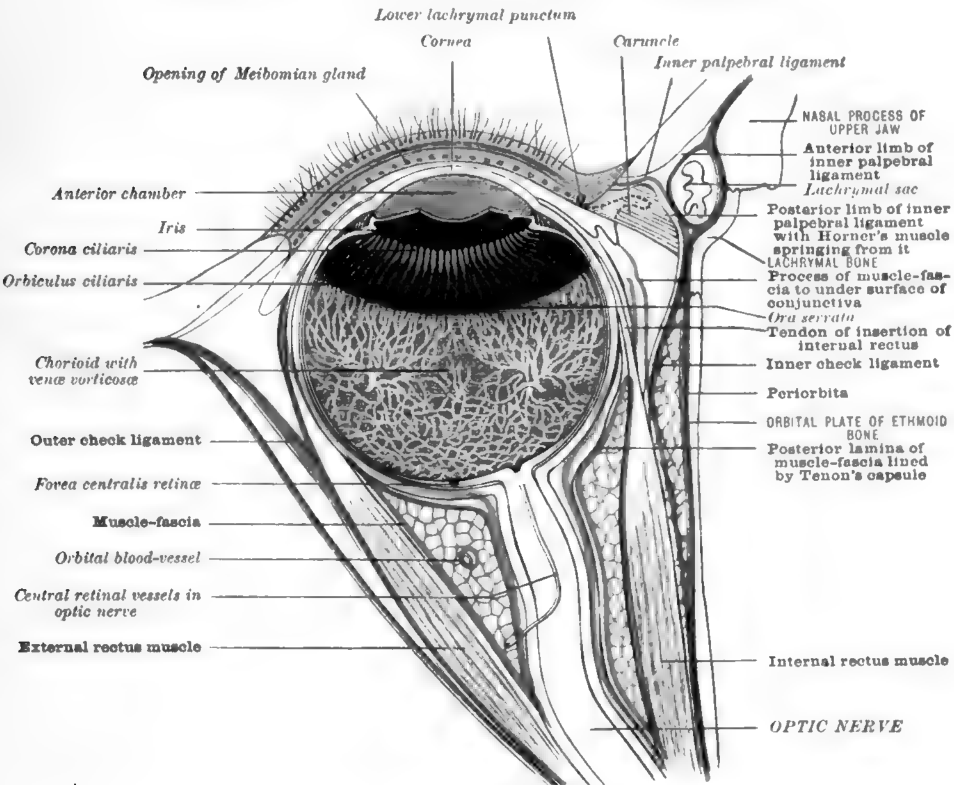
In front of the ora serrata the uveal coat becomes considerably modified, and the part reaching from here to the iris may conveniently be termed the ciliary region of the tract, or **ciliary body.** Its superficial aspects have been already briefly described. In front, the ciliary processes, about seventy in number, project towards the interior of the eye, forming the **corona ciliaris.** Behind this part lies the **orbiculus ciliaris,** whose inner surface is almost smooth, faint radial folds only being present, three or four of which join each ciliary process. The more minute structure of this ciliary region resembles closely that of the chorioid, except that the chorio-capillaris is no longer present, that the stroma is thicker and richer in blood-vessels, and that a muscular element (ciliary muscle) exists between the vascular layer and the membrana suprachorioidea. On antero-posterior section the ciliary body is triangular; the shortest side looks forwards, and from about its middle the iris arises; the two long sides look respectively inwards and outwards, the inner having the ciliary processes upon it, while the outer is formed by the **ciliary muscle.** This muscle possesses smooth fibres and consists of an outer and an inner division; in the outer the fibres run longitudinally, inserted into the outer fibrous coat of the eye at the sclero-corneal junction in front, and passing backwards to join the outer layers of the orbiculus and chorioid; the inner contains circularly running fibres situated next to the ciliary processes. The entire muscle is destitute of pigment, and therefore is recognisable in the section by its light colour. The whole thickening of the uveal tract in this region, muscle and folds and processes together, is named the ciliary body.

The **iris** projects into the interior of the front half of the eye in the form of a circular disc perforated in the middle. The appearance of its anterior surface has

already been described. Its posterior surface exhibits numerous radial folds running from the ciliary processes to near the pupillary border; a thick layer of black pigment covers it and curls around its inner edge, so as to come into view all around the pupil as seen from in front. The peripheral or ciliary border of the iris is continuous with the front of the ciliary body, where it also receives fibres from the ligamentum pectinatum iridis; in other respects the iris is quite free, merely resting on the front of the lens-capsule near the pupil. Its stroma is spongy in character, being made up of vessels covered by a thick adventitia, running from the periphery to the pupillary border, with interspaces filled by branching pigment cells, which are particularly abundant near the front surface. Deep in the stroma, running around near the pupillary border, we find a broad flat band of smooth muscle-fibres, constituting the **sphincter pupillæ** or **sphincter iridis.** Immediately behind the

Fig. 727.—Diagrammatic Horizontal Section of Eyeball and Orbit. (After Fuchs, much modified.)

Periorbita *green;* muscle-fascia *red;* Tenon's capsule *yellow.*



vascular tissue lies a thin membrane, consisting of fine, straight fibres running radially from the ciliary border to just behind the sphincter. The nature of these fibres was long in dispute, but they are now accepted as being undoubtedly smooth muscular—the **dilator pupillæ.**

The sphincter pupillæ and the ciliary muscle are supplied by the third nerve by way of the ciliary ganglion. The dilator pupillæ is supplied by sympathetic fibres, which have their origin from the cells of the superior cervical ganglion. Thence they ascend in the carotid and cavernous plexuses, and join the ophthalmic division of the fifth nerve, passing to the eyeball by way of the long ciliary nerves. The white rami fibres associated with these fibres leave the spinal cord by the motor roots of the first two or three thoracic nerves, and ascend the sympathetic trunk to the superior cervical ganglion without interruption.

Posteriorly the iris is lined by the pigment already mentioned, which really

consists of two layers of pigmented cells, each layer representing the extension forwards of one subdivision of the retina. The front of the iris is covered by a delicate epithelial layer, a continuation of that lining Descemet's membrane. The colour of the iris in different individuals depends upon the amount of *stromal* pigment.

3. **The innermost or nervous coat.**—The inner surface of the uveal tract is everywhere lined by a layer of pigment of corresponding extent, which usually adheres to it closely on dissection. Developmentally, however, this general pigment lining is quite distinct from the uveal coat, and represents the *outer wall* of the secondary optic vesicle or embryonic retina: it consists of a single layer of pigmented epithelial cells. The amount of pigment is greatest anteriorly, over the ciliary region and iris, and there is again a small local increase posteriorly, corresponding to the macula lutea and to the edge of the optic nerve-entrance. In the ciliary region these cells have recently been described as lining numerous narrow tubular depressions in the inner part of the uveal tract, and they are said to have here a special function, viz., that of secreting the intraocular fluid.

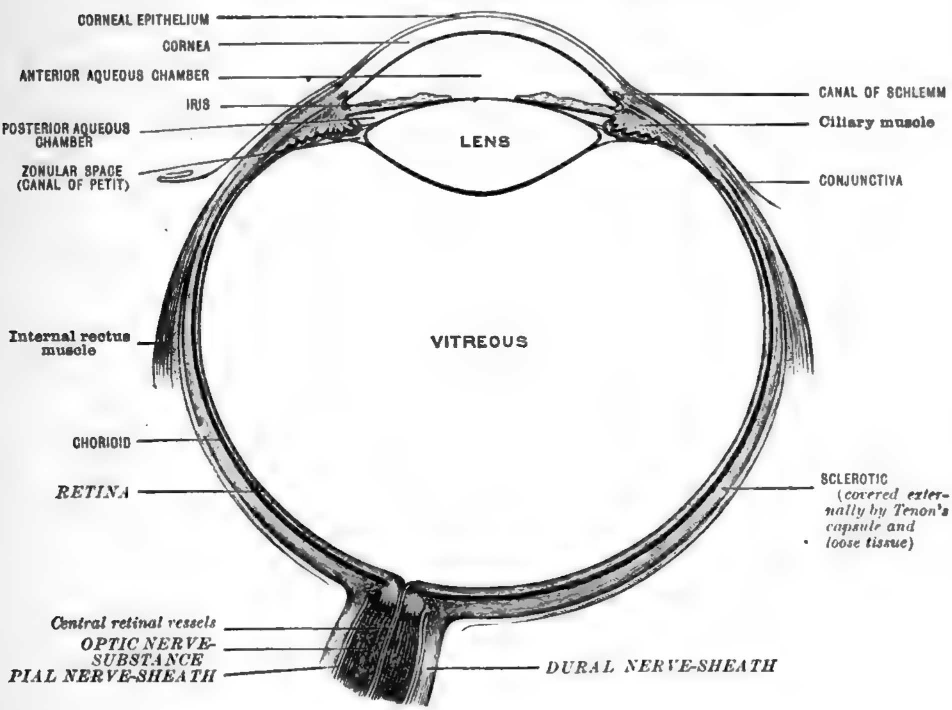
From the manner in which the secondary optic vesicle, or *optic cup*, is formed, its two walls are necessarily continuous in front, at what may be termed the *lip* of the cup; we have just observed that the outer wall lines the uveal coat everywhere and corresponds in extent; consequently, the lip must be looked for at the edge of the pupil, i. e., at the termination of this coat anteriorly. The *inner wall* of the cup, consequently, reaches from the lip, or pupillary edge, in front, to the optic stalk or nerve behind, and is in close apposition to the pigment-epithelium; unlike the outer, however, this wall is represented in the developed eye by tissues very dissimilar in structure in different parts of its extent. Tracing it backwards from the pupillary edge, we find that over the whole posterior surface of the iris it exists as a single layer of pigmented epithelium, the developmental changes having here produced a result similar to what we have found throughout in the outer wall: here, accordingly, we have a double layer of pigment cells. At the root of the iris the single inner layer of cells still exists; but now they become destitute of pigment, and this condition obtains over the entire ciliary region, constituting what is known as the **pars ciliaris retinæ.** At the line of the ora serrata the tissue derived from the inner wall abruptly increases in thickness, and rapidly acquires that complexity of structure characteristic of the **retina proper,** which extends from here to the optic nerve. It consists of several layers—nerve-fibres, nerve-cells, and nerve-epithelium—held together by a supporting framework of delicate connective tissue. The nerve-epithelium is on the outer surface, immediately applied to the pigment-epithelium; at the posterior pole of the eye a small spot (**fovea centralis**) exists, where this is the only retinal layer represented, and where consequently the retina is extremely thin. The nerve-fibres run on the inner surface of the retina and are continuous with those of the optic nerve; they constitute the only retinal layer that is continued into the intraocular end of the nerve. The nerve-cells are found between these surface layers. The larger blood-vessels of the retina run in the inner layers, and none encroach on the layer of nerve-epithelium.

Within the coats mentioned, the interior of the eyeball is fully occupied by contents, which are divided into three parts, and differently named according to their consistence and anatomical form. They are all transparent, as through them the light has to pass so as to gain the retina. Of these, the only one that is sharply and independently outlined is the lens, which is situated in the anterior half of the globe at the level of the ciliary processes, where it is suspended between the other contents, which fill respectively the space in front of it and the space behind it. The space in front is called the anterior or aqueous chamber; that behind the lens is the vitreous chamber.

The **lens** is a biconvex body, with its surfaces directed anteriorly and posteriorly; these surfaces meet at its rounded-off edge or **equator,** which is near (but does not touch) the ciliary processes all around. The posterior is considerably more convex than the anterior surface; the central part of each surface is called its **pole.** The lens is closely encased in a hyaline elastic capsule, thicker over the anterior than over the posterior surface. Thus enclosed, it is held in position in the globe by a suspensory ligament, attached to its capsule near the equator all around, and swung from the ciliary region. Posteriorly, the lens rests in a cup formed by the front part of the vitreous, while its anterior capsule is in contact with the aqueous fluid and lies close against the back of the pupillary border of the iris. When in position

the lens measures nine millimetres across, and about four millimetres between its poles. On each surface a series of fine, sinuous, grey lines can be seen radiating from the pole towards the equator, called respectively the anterior and posterior **stellate figures.** The lines observable on the posterior are always so placed as to be intermediate with those on the anterior surface, so that on viewing them *through the lens* they occupy a position corresponding to the intervals between the lines on the anterior surface. The lens-capsule is comparatively brittle, and can be readily cut through when scraped with a sharp-pointed instrument; on doing so the divided edges curl outwards, away from the lenticular substance. When removed from its capsule, the outer portion of the lens is found to be soft and glutinous, but its substance gets progressively firmer as we approach the centre. This harder central part is known as the **nucleus,** and the surrounding softer matter as **cortex.** The cortical part shows a tendency to peel off in successive layers. It consists of

FIG. 728.—SEMI-DIAGRAMMATIC HORIZONTAL SECTION THROUGH EYEBALL AND OPTIC NERVE. (After Elfinger. Reduced and altered.)



long fibres, the ends of which meet in front and behind at the anterior and posterior stellate figures.

Histologically the capsule is not in immediate contact with the cortex over the front surface of the lens, a single layer of cells intervening, called the **subcapsular epithelium.**

The **zonula ciliaris** or **suspensory ligament of the lens** is formed by a thickening of the anterior part of a membrane enclosing the vitreous, strengthened by numerous fibres derived from the folds of the ciliary region. Its chief attachments to the lens-capsule are a little in front of and behind the equator, and the space included between the most anterior and most posterior divisions of the ligament is termed the zonular space (**canal of Petit**). This space is bridged across by fine intermediate suspensory fibres, and is occupied by fluid.

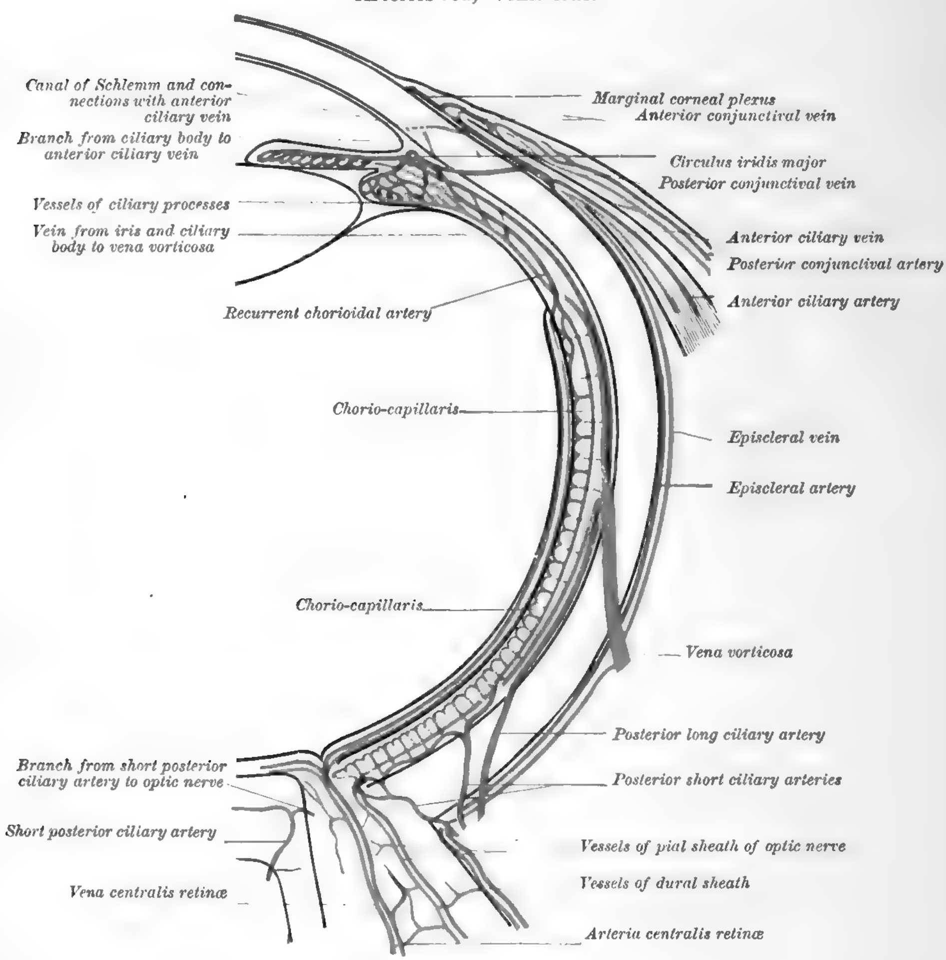
The **vitreous humour** is a transparent, colourless, jelly-like mass, enclosed in a delicate, clear, structureless membrane, called the *hyaloid membrane.* This latter is closely applied to the back of the posterior lens-capsule and of the suspensory ligament, and to the inner surface of the pars ciliaris retinæ, retina proper, and optic papilla. Although possessing some degree of firmness, the vitreous humour contains quite 98 per cent. of water, and has no definite structure. Membranes

have been described in it, but these are really artificial products. In certain situations spaces exist in the vitreous mass, the most determinate of which runs in the form of a canal from the optic papilla to the posterior pole of the lens, corresponding to the position of the fœtal hyaloid artery (**hyaloid canal,** or **canal of Cloquet**). Other very fine spaces are described running circularly in the peripheral part of the vitreous concentric with its outer surface. Microscopically, wandering cells are found in the vitreous, which often here assume peculiar forms which the observer can, not infrequently, study subjectively.

The **aqueous humour** is a clear, watery fluid, occupying the space between the cornea on the one hand, and the ciliary body, suspensory ligament, and lens on

FIG. 729.—DIAGRAMMATIC REPRESENTATION OF THE BLOOD-VESSELS OF THE EYEBALL. (Leber.)

Arteries *red;* veins *blue.*



the other. The iris, projecting into this space, has both its surfaces bathed in the aqueous; but, as its inner part rests on the lens, it is regarded as dividing the space into two parts, an **anterior** larger, and a **posterior** smaller, **aqueous chamber,** which communicate freely through the pupil.

Ciliary nerves of the eyeball.—The long and short ciliary nerves, after perforating the sclerotic, run forwards between it and the chorioid to the ciliary region, where they form a plexus, from which proceed branches for the ciliary muscle, the iris, and the cornea. The nerves of the iris enter it at its ciliary border, and run towards its pupillary edge, losing their medullary sheath sooner or later, and sup-

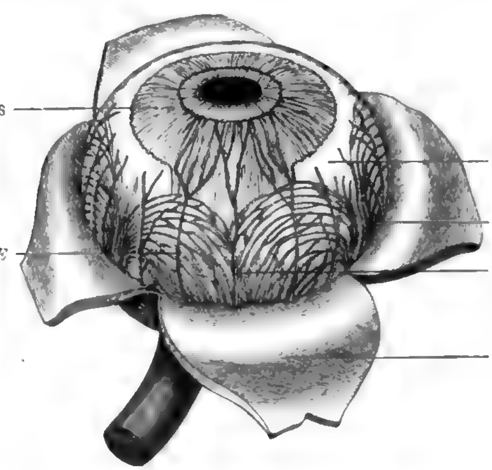
plying especially the sphincter muscle. The corneal nerves form an annular plexus near the limbus, from which a few twigs proceed to the sclerotic and conjunctiva, while most of the offsets enter and run radially in the corneal stroma, branching and anastomosing so as to form a plexus. The nerves entering the cornea are about sixty in number, each containing from two to twelve non-medullated nerve-fibres (page 972).

Blood-vessels of the eyeball.—The ocular tissues receive blood from two sets of vessels, viz., the **retinal** and the **ciliary arteries.**

1. The **arteria centralis retinæ** either comes direct from the ophthalmic artery, or from one of its branches near the apex of the orbit. Entering the optic nerve twenty millimetres or less behind the globe, it runs forwards in its axis to the end of the nerve-trunk, and then divides into branches which run in the inner layers of the retina, and divide dichotomously as they radiate towards the equator. The smaller branches lie more deeply in the retina, but none penetrate into the nerve-epithelium, so that the fovea centralis is non-vascular. In the retina, the branches of the central artery do not communicate with any other arteries, but while still in the optic nerve fine communications take place between this artery and neighbouring vessels. Thus (*a*) minute twigs from it, which help to nourish the axial part of the nerve, communicate with those running in the septa derived from the pial sheath. Again,

FIG. 730.—SURFACE OF CHORIOID AND IRIS EXPOSED BY REMOVAL OF SCLEROTIC AND CORNEA, SHOWING DISTRIBUTION OF BLOOD-VESSELS AND NERVES.

(Twice natural size. After Zinn.)



as the nerve passes through the sclerotic, it is surrounded by a vascular ring (circle of Haller), formed of fine branches derived from the short posterior ciliary arteries; fine twigs passing inwards from this ring to the optic nerve join the vessels of the pial sheath, and (*b*) an indirect communication is thus brought about between the retinal and ciliary vessels. Finally, as the nerve passes through the chorioid, there is (*c*) a direct connection between these two sets of vessels, the capillary network of the optic nerve being here continuous with the chorio-capillaris. Not infrequently, a branch from a short posterior ciliary artery pierces the optic papilla, and then courses over the adjoining retina (a cilio-retinal artery), supplying the latter in part in place of the central artery.

The **vena centralis retinæ** returns the blood of the corresponding artery.

2. **The ciliary system of blood-vessels** (pages 536, 537, and 662).—There are three sets of arteries belonging to this system, all derived directly or indirectly from the ophthalmic artery.

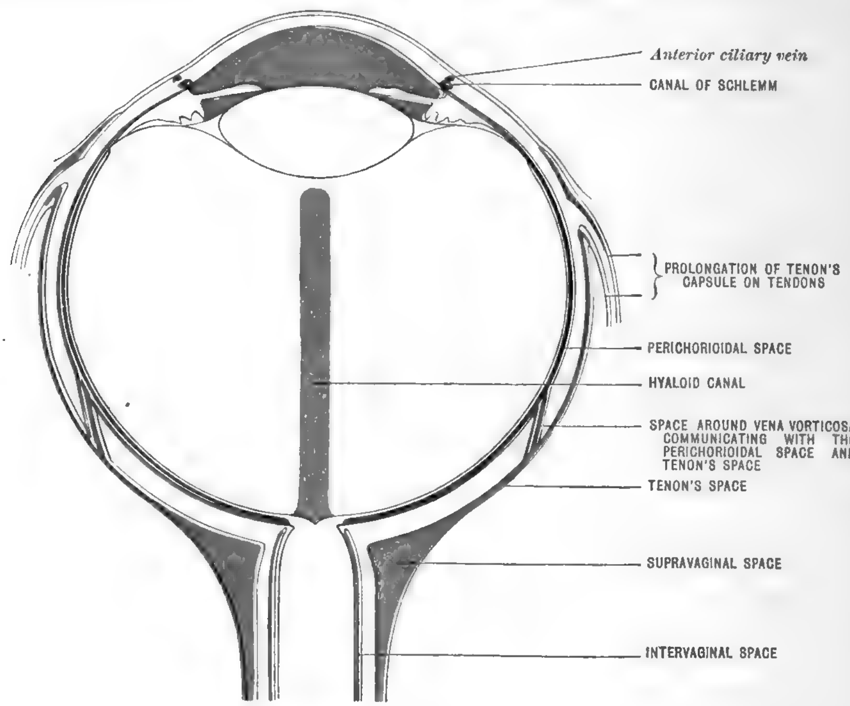
(1) **Short posterior ciliary arteries,** twelve to twenty in number, pierce the sclerotic round the optic nerve entrance, and are distributed in the chorioid. Before entering the eyeball, small twigs are given off to the adjoining sclerotic and to the dural sheath of the optic nerve.

(2) Two **long posterior ciliary arteries,** piercing the sclerotic further from the

nerve than the short ciliaries, run horizontally forwards between the sclerotic and chorioid, one on each side of the globe. On arriving at the ciliary body, they join with the anterior ciliary arteries, forming the **circulus arteriosus major,** which sends off branches to the ciliary processes and the iris. The long ciliaries also give twigs to the ciliary muscle, and small recurrent branches run backwards to anastomose with the short ciliary arteries. The arteries of the iris run radially towards the pupillary border, anastomosing with one another opposite the outer border of the sphincter so as to form the **circulus arteriosus minor.**

(3) The **anterior ciliary arteries** come from the arteries of the four recti muscles, one or two from each; they run forwards, branching as they go, and finally pierce the sclerotic near the corneal border. Outside the globe they send twigs to the adjoining sclerotic, to the conjunctiva, and to the border of the cornea. After passing through the sclerotic the arteries enter the ciliary muscle, where they end in twigs to the muscle and to the circulus arteriosus major, and in recurrent branches to the chorioid.

FIG. 731.—THE LYMPHATIC SPACES OF THE EYEBALL. (Diagrammatic. After Fuchs.)



Veins.—The venous blood from almost the whole uveal tract (chorioid, ciliary processes and iris, and part of the ciliary muscle) ultimately leaves the eyeball by—(1) the **venæ vorticosæ,** which have been already noticed in describing an antero-posterior section through the globe (p. 1025). One large vein passes backwards from each vortex, piercing the sclerotic obliquely; it is joined by small episcleral veins when outside the globe.

(2) The **anterior ciliary veins** commence by the junction of a few small veins of the ciliary muscle; they pass outwards through the sclerotic near the corneal border, receiving blood from the veins in connection with Schlemm's canal, and afterwards from episcleral and conjunctival veins, and from the marginal corneal plexus. Finally they join the veins running in the recti muscles.

Lymphatic system of the eyeball.—Apart from those in the conjunctiva there are no lymphatic *vessels* in the eyeball, but the fluid is contained in *spaces* of various sizes. These are usually divided into an anterior and a posterior set.

1. **Anteriorly,** we have the anterior and posterior aqueous chambers, which communicate freely through the pupil. The aqueous humour is formed in the

posterior of these chambers by transudation from the vessels of the ciliary body and posterior surface of the iris (see also page 1030). The stream passes mainly forwards through the pupil into the anterior aqueous chamber, whence it escapes slowly by passing through the spaces of Fontana into Schlemm's canal, and thence into the anterior ciliary veins. Part of the lymph-stream passes from the posterior aqueous chamber backwards into the zonular space (canal of Petit), out of which fluid can pass into the lens substance, or diffuse itself into the front of the vitreous.

In the **cornea** the lymph travels in the spaces already mentioned as existing between the fibre-bundles, and in the nerve-channels and at the periphery of the cornea it flows off into the lymphatic vessels of the conjunctiva.

In the **iris** there is a system of lymphatic spaces opening anteriorly on its free surface by the crypts previously described, and communicating peripherally with the spaces of Fontana.

2. **Posteriorly,** we have (*a*) the central or hyaloid canal, between the posterior pole of the lens and the optic nerve entrance, and (*b*) the perivascular canals of the retina; the lymph from both of these situations flows into the spaces of the optic nerve, which communicate with the intervaginal space of the nerve, and thus with the great intracranial spaces. Further, between chorioid and sclerotic we have (*c*) the perichorioidal space, which gets the lymph from the chorioid, and communicates with Tenon's space outside the sclerotic by the perforations corresponding to the vasa vorticosa and posterior ciliary arteries, and with the intervaginal space around the optic nerve entrance. Tenon's space, again, is continuous with the supravaginal space around the optic nerve, which communicates both with the intervaginal spaces, with the lymph-spaces of the orbit, and directly with the intracranial spaces at the apex of the orbit.

The development of the eye.—Three different embryonic tissues take part in the formation of the eye, namely, an outgrowth from the central nervous system, an invagination of the surface ectoderm, and the mesoderm tissue in the vicinity of these two structures. From the outgrowth from the brain the retina in all its parts and the optic nerve develope, from the surface invagination the lens, and the remaining structures are formed from the mesoderm. The vitreous may also possibly have a partial origin from the primitive retinal tissues.

The central outgrowth takes the form of a hollow bulb attached to the brain by a long slender stalk. When by its growth it comes into contact with the lens invagination, the outer half of the bulb sinks back into its cavity until it comes into contact with the wall of the posterior half, and the bulb is thus converted into a cup. But the cup is an incomplete one, for its entire ventral wall and a portion also of that of the stalk become pushed up into the cavities of these structures, so that along their ventral surfaces there is a deep fissure known as the *chorioidal fissure.* In normal development the fissure is eventually obliterated by the union of its lips, but occasionally it persists more or less completely, producing the condition known as *coloboma.*

In the fissure an artery and vein develope and so reach the cavity of the optic cup. When the fissure closes they become enclosed and form the arteria and vena centralis retinæ. In the embryonic condition branches from these vessels extend through the vitreous and form a vascular tissue almost completely investing the lens, which occupies the mouth of the cup. These hyaloid vessels normally disappear later, leaving only the hyaloid canal as a reminder of their existence, but occasionally traces of them may persist over the anterior surface of the lens, forming what is termed a persistent pupillary membrane, or in the vitreous as a persistent hyaloid artery.

CAVITY OF THE ORBIT

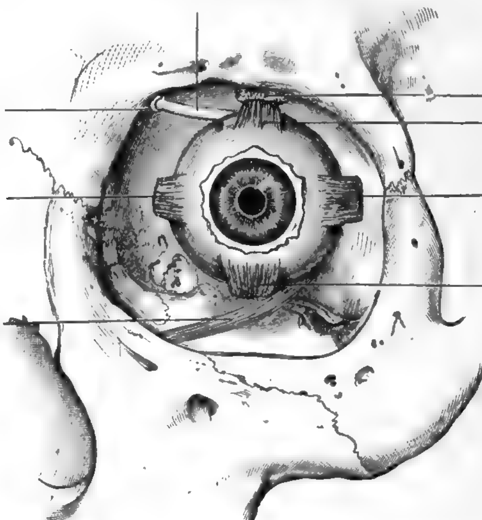
General Arrangement of its Contents

The anterior wider half of the cavity is mainly occupied by the eyeball, which lies almost axially, but is rather nearer to the upper and outer than it is to the other walls. The posterior two-thirds of the globe are in relation with soft parts, chiefly muscles and fat, and its posterior pole is situated midway between the base (or opening) and the apex of the orbital cavity. The anterior third of the eyeball is naturally free, except for a thin covering of the conjunctiva, and projects slightly beyond the opening of the orbit, the degree of prominence varying with the amount of orbital fat, and also to some extent with the length of the globe. A straight line joining the inner and outer orbital margins usually cuts the eye behind the cornea—externally behind the ora serrata, nasally further forwards, at the junction of the ciliary body and iris. The globe is held in position by numerous bands of connective tissue. The lachrymal gland lies under the outer part of the roof of the orbit anteriorly. The orbital fat occupies the spaces between the orbital

muscles, and is in greatest amount immediately behind the eyeball; it also exists between the muscles and the orbital walls in the anterior half of the cavity. Six muscles, viz., the four recti, the superior oblique, and the levator palpebræ superioris, arise at the apex of the orbit, and diverge as they pass forwards. The recti muscles—superior, inferior, external, and internal—run each near the corresponding orbital wall, but the superior is overlapped in part by the levator palpebræ. The superior oblique lies about midway between the superior and internal recti. A seventh muscle, the inferior oblique, has a short course entirely in the anterior part of the orbit, coming from its inner wall and passing beneath the globe between the termination of the inferior rectus and the orbital floor. The optic nerve with its sheaths passes from the optic foramen to the back of the eyeball, surrounded by the orbital fat, and more immediately by a loose connective tissue. Among the contents of the cavity are also to be enumerated many vessels and nerves and fibrous tissue septa, while its walls are clothed by periosteum (periorbita).

The **muscles of the orbit** are seven in number, of which six are *ocular*, i. e., are inserted into the eyeball and rotate it in different directions. These ocular muscles are arranged in opponent pairs, viz., **superior** and **inferior recti, superior** and **inferior obliques, external** and **internal recti.** With the exception of the short

Fig. 732.—Left Eyeball seen in its Normal Position in the Orbit, with View of the Ocular Muscles. (After Merkel, modified.)



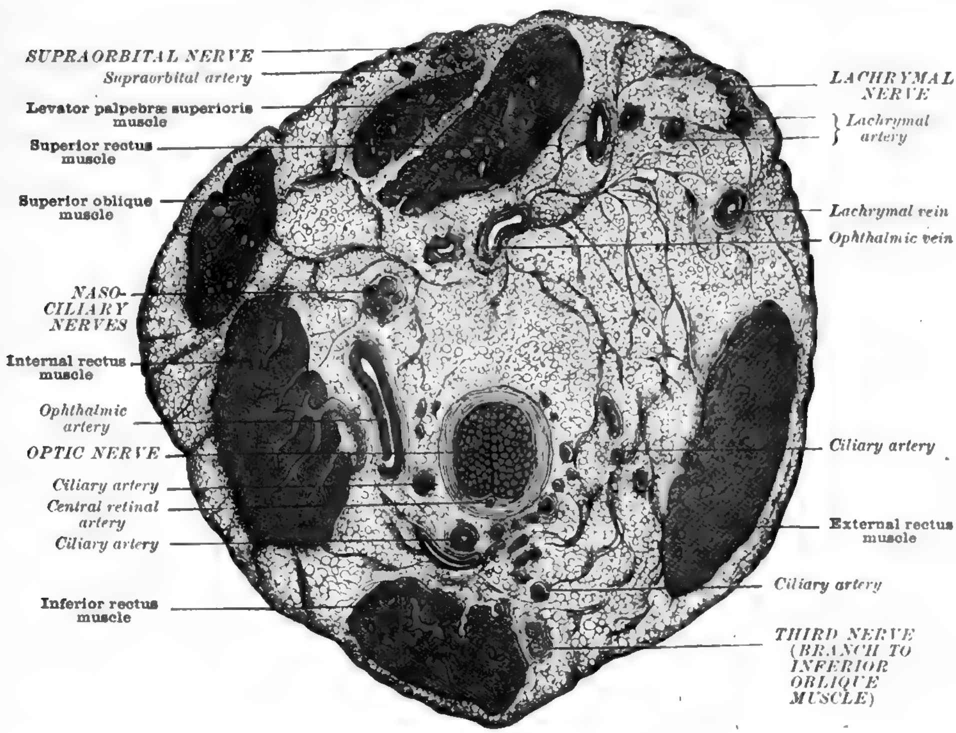
inferior oblique, they all arise from the back of the orbit along with the seventh orbital muscle, the **levator palpebræ superioris.** All these long muscles take their origin from the periosteum in the vicinity of the optic foramen. The four recti muscles arise from a fibrous ring, the **annulus tendineus communis (ligament of Zinn),** which arches close over the upper and inner edge of the foramen, and extends down and out so as to embrace part of the opening of the superior orbital (sphenoidal) fissure. Their origins may be said at first to form a short, common, tendinous tube, from which the individual muscles soon separate, taking the positions indicated by their respective names. The external rectus has two origins from bone, one on either side of the superior orbital fissure. But in the fresh state the fissure is here bridged across by fibrous tissue, from which this rectus also springs, so that its origin is in reality continuous. The part of this fibrous ring nearest the foramen (corresponding to the origins of the superior and internal recti) is closely connected with the outer sheath of the optic nerve. The remaining two long muscles arise just outside the upper and inner part of the above-mentioned ring, and are often partially united; the levator palpebræ tendon is in close relation to the origin of the superior rectus, while the superior oblique arises from the periosteum

of the body of the sphenoid bone one or two millimetres in front of the origin of the internal rectus.

The **four recti muscles** lie rather close to the corresponding orbital walls for the first half of their course, the superior rectus, however, being overlapped in part by the levator palpebræ; they then turn towards the eyeball, running obliquely through the orbital fat, and are finally inserted by broad, thin tendons into the sclerotic in front of the equator. From their respective positions in the orbit, the axis of this cone of muscles is oblique to the antero-posterior axis of the eyeball. The thickest of these muscles is the internal rectus, next the external, then the inferior, and the superior rectus is the thinnest. As regards length, the muscular belly of the superior rectus has the longest course, and the others diminish in the order—internal, external, and inferior rectus. The external rectus is supplied by the sixth nerve. The other three recti muscles are all supplied by the third nerve.

The **levator palpebræ superioris** courses along the roof of the orbit close to the periosteum for the greater part of its course, partially overlapping the superior

FIG. 733.—SECTION THROUGH CONTENTS OF RIGHT ORBIT 8–11 MM. BEHIND THE EYEBALL, VIEWED FROM BEHIND. (After Lange.)



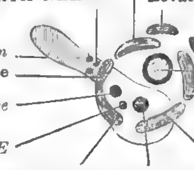
rectus; it finally descends through the orbital fat, and widens out to be inserted into the root of the upper lid. It may be briefly described as being inserted in two distinct layers separated by a horizontal interval. The upper or anterior layer of insertion is fibrous, and passes in front of the tarsus, where it comes into relation with fibres of the orbicularis. The lower layer consists of smooth muscle (Müller's **superior tarsal muscle**), and is inserted along the upper border of the tarsus. The levator has also connections with the sheath of the superior rectus. These different insertions of the muscle will be referred to later along with the description of the orbital fasciæ and of the upper eyelid. It gets its nervous supply from the third nerve, but the smooth muscle developed in its lower layer of insertion is supplied by the sympathetic nervous system. As its name expresses, its *action* is to raise the upper lid and to support it while the eye is open.

The **superior oblique** runs forwards close to the inner part of the orbital roof until it reaches the fossa trochlearis near the internal angular process, where it becomes tendinous and passes through a fibro-cartilaginous pulley attached to the

fossa just named. On passing through this pulley, or **trochlea,** the tendon bends at an angle of 50°, running backwards and outwards under the superior rectus to its insertion into the sclerotic. It is supplied by the fourth nerve.

The **inferior oblique** arises from the front of the orbit, about the junction of its inner and lower walls, just external to the lower end of the lachrymal groove. It runs, in a sloping direction, outwards and backwards, lying at first between the inferior rectus and the orbital floor, then between the external rectus and the globe;

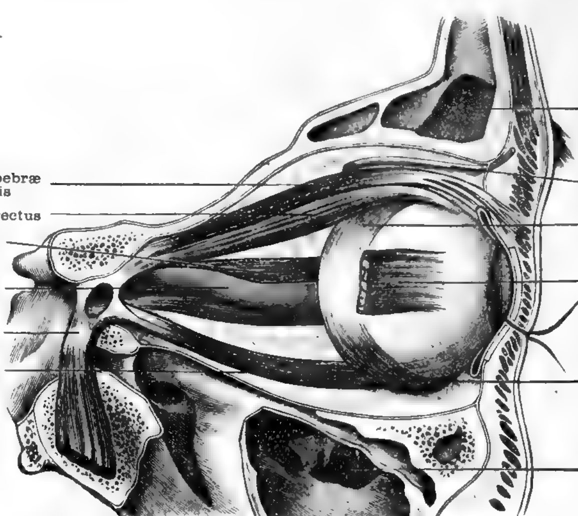
Fig. 734.—Diagrammatic Representation of Origins of Ocular Muscles at the Apex of the Right Orbit.
(After Schwalbe, slightly altered.)



finally it ascends slightly, to be inserted by a short tendon into the sclerotic at the back of the eye. Its nervous supply is derived from the third nerve. The precise manner of insertion of the different ocular muscles has been described above in our Examination of the Eyeball. (For Muscles of the Eyelids and Eyebrows, see pages 331 and following.)

Action of the ocular muscles.—While rotating the globe so that the cornea is turned in different directions, the ocular muscles do not alter the position of the eyeball in the orbit either laterally, vertically, or antero-posteriorly. In speaking,

Fig. 735.—The Muscles of the Eye seen from the Temporal Side.
(After Testut.)



therefore, of the eye being moved *upwards* or *outwards*, etc., it is the altered position of the cornea or front of the eye that we mean to express; it is manifest that, if the cornea moves up, the back of the eyeball must simultaneously be depressed, and similarly with other movements. All the movements of the globe take place by rotation, on axes passing through the centre. Though the possible axes are numerous in combined muscular action, there are three **principal axes** of rotation of the eyeball, and in reference to these the action of individual muscles must be described.

Two of these axes are horizontal and one vertical; they all pass through the centre of rotation at right angles to one another. By rotation of the eye on its vertical axis the cornea is moved outwards (towards the temple) and inwards (towards the nose): movements called respectively **abduction** and **adduction.** In upward and downward movements of the cornea the eye rotates on its horizontal equatorial axis. The other principal axis of rotation is the sagittal, which we have previously described as corresponding to the line joining the anterior and posterior poles of the globe (page 1023). In rotation of the eye on its sagittal axis, therefore, the cornea may be said to move as a wheel on its axle, for its centre now corresponds to one end of the axis; in other words, this is a **rotation of the cornea.** Such movements may, consequently, be expressed with reference to their effect on an imaginary spoke of the corneal wheel—e. g., one running vertically upwards from the corneal centre. Thus we may say 'rotation of the cornea outwards' when this part of the wheel moves towards the outer canthus, or 'inwards' when towards the nose.

The only two muscles that rotate the eyeball merely on one axis are the **external rectus** and the **internal rectus;** the former abducting, and the latter adducting, the cornea. The action of the superior and inferior recti is complicated by the obliquity of the axes of muscles and globe previously mentioned.

Fig. 736.—View of Left Orbit from above, showing the Ocular Muscles. (From Hirschfeld and Leveillé.)

The chief action of the **superior rectus** is to draw the cornea upwards, but at the same time it adducts and rotates the cornea inwards.

The **inferior rectus** mainly draws the cornea downwards, also adducting it and rotating it outwards.

The chief action of the **superior oblique** is to rotate the cornea inwards, also drawing it downwards and slightly abducting it.

The **inferior oblique** mainly rotates the cornea outwards, also drawing it upwards and slightly abducting it.

The fasciæ of the orbit.—The orbital contents are bound together and supported by fibrous tissues, which are connected with each other, but which may conveniently be regarded as belonging to three systems. These are:—(1) Those lining the bony walls; (2) those ensheathing the muscles; and (3) the tissue which partially encapsules the eyeball.

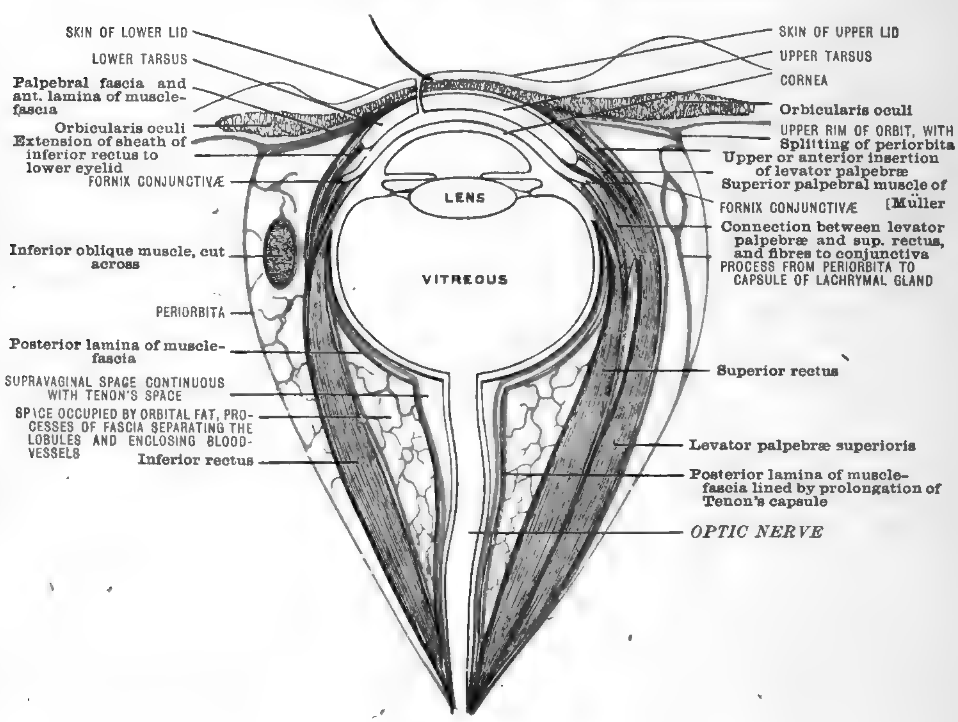
1. The **orbital periosteum,** or **periorbita,** is closely applied to the bones forming the walls of the cavity, but may be stripped off with comparative ease. It presents openings for the passage of vessels and nerves entering and leaving the orbit. Posteriorly this tissue is very firm, being joined by processes of the dura mater at the optic canal and superior orbital fissure; at the optic foramen it is also

connected with the dural sheath of the optic nerve. As it covers the inferior orbital (spheno-maxillary) fissure its fibres are interwoven with smooth muscle, forming the **orbital muscle** of Müller. From its inner surface processes run into the orbital cavity, separating the fat lobules. One important process comes from the periorbita about midway along the roof of the orbit, runs forwards to the back of the upper division of the lachrymal gland, and there splits, helping to form the gland-capsule: this capsule is joined at its inner border by other periorbital bands coming off near the upper orbital rim, and forming the suspensory ligament of the gland. On the inner side of the orbit the periorbita sends fibrous processes to the trochlea of the superior oblique, which keep it in position. On arriving at the lachrymal groove the periorbita divides into two layers, a thin posterior one continuing to line the bone forming the floor of the groove, whilst the thicker anterior layer bridges over the groove and the sac which lies in it, forming the limbs of the inner palpebral ligament (page 1046).

FIG. 737.—VERTICAL SECTION THROUGH THE EYEBALL AND ORBIT IN THE DIRECTION OF THE ORBITAL AXIS, WITH CLOSED EYELIDS.

(Semi-diagrammatic. After Schwalbe, modified to show fasciæ.)

Periorbita *green;* muscle-fascia *red;* Tenon's capsule *yellow.*



Quite anteriorly, at the rim of the orbit, the periorbita sends off a membranous process which aids in forming the fibrous tissue of the eyelids (**orbito-tarsal ligament,** or **palpebral fascia**), and is itself continuous with the periosteum of the bones outside the orbital margin.

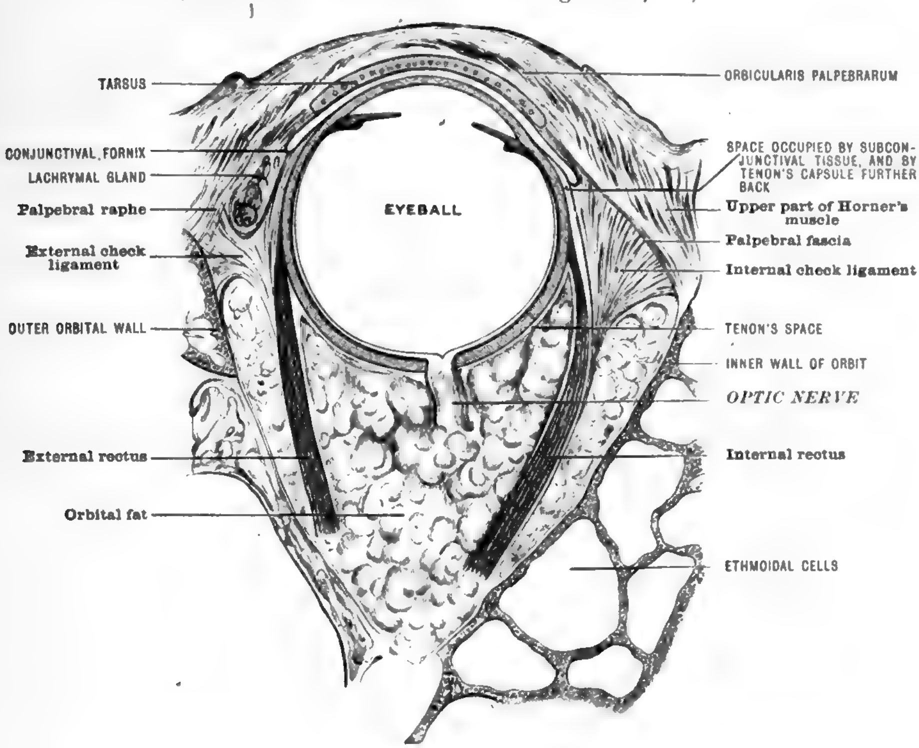
2. The orbital muscles are connected by a common fascia, which splits at their borders and furnishes a sheath to each. Processes of this fascia give membranous investments for the vessels and nerves (including the optic nerve), splitting similarly to enclose them; these membranous processes also assist in separating the fat lobules. Posteriorly, this fascia is thin and loose, and blends with the periorbita at the origin of the muscles. Anteriorly, it becomes thicker and firmer, accompanies the muscles to near the equator of the eyeball, and there divides into two laminæ, an anterior and a posterior; the former continues a forward course, forming a complete funnel-shaped investment all around, passing ultimately to the eyelids and

orbital margin—whilst the latter turns backwards, covering the hinder third of the globe.

The *anterior lamina* is a well-marked membrane everywhere, but in certain situations it presents special bands of thickening, corresponding to the direct continuation forwards of the sheath of each rectus muscle. Above and below, this lamina spreads out in the form of two large membranes, which are finally applied to the deep surface of the palpebral fascia; the lower membrane constitutes what has been described as 'the suspensory ligament of the eyeball.' The upper membrane requires a fuller description, as its distribution is modified by the presence of the levator palpebræ muscle.

The upper part of the sheath of the superior rectus (along with the adjoining membrane on each side of it) passes to the deep surface of the levator, to which it closely adheres, and completely ensheaths this tendon by extending round its borders to its upper surface. The lower part of this levator sheath is applied to the

FIG. 738.—HORIZONTAL SECTION THROUGH LEFT ORBIT, VIEWED FROM ABOVE. (After von Gerlach. To show check ligaments, etc.)



inferior surface of the deeper of the two divisions of the levator muscle, *superior tarsal muscle* of Müller), and is attached to the upper border of the tarsus of the upper lid, reaching laterally to the outer and inner angles of the orbit. The upper part of the sheath of the superior tarsal muscle reaches to the middle of the palpebral fascia, and is mainly continued forwards between the muscle and the fascia to the anterior surface of the tarsus.

The lower membrane (suspensory ligament of the eyeball), joined by the sheath of the inferior rectus, reaches forwards to the attached (hinder) border of the tarsus of the lower lid, where it is mainly attached, while a part of it extends to the lower palpebral fascia.

To understand the *special bands* of the anterior lamina mentioned above, we must follow the sheath of each rectus muscle forwards, when we find that, while it is rather loosely applied to the muscular belly in its posterior two-thirds, it then suddenly becomes thicker, and is firmly attached to the muscle for some distance before finally leaving it, and is thereafter often accompanied by some muscle-fibres. The

best developed of these bands, the *external check ligament*, passes forwards and outwards to the outer angle of the orbit, helping to support the lachrymal gland on its way, and is inserted near the orbital edge immediately behind the external palpebral ligament. The inner band, or *internal check ligament*, is larger than the outer, but not so thick; it passes forwards and inwards to be inserted into the upper part of the lachrymal crest and just behind it. These two bands, external and internal, come from the sheaths of the corresponding recti muscles. From the sheath of the superior rectus come two thin bands, one from each border. The inner joins the sheath of the tendon of the superior oblique; the outer goes to the external angle of the orbit, assisting in the support of part of the lachrymal gland. The sheath of the inferior rectus is thickened in front, and, on leaving the muscle, goes to the middle of the inferior oblique, splitting to enclose it; it then passes to be inserted into the lower inner angle of the orbit close behind its margin, about midway between the internal check ligament and the orbital attachment of the inferior oblique.

3. In addition to its partial investment by the muscle-fascia, the eyeball has a special membrane enclosing its hinder two-thirds, the **fascia bulbi** or **Tenon's capsule.** This is a thin, transparent tissue, situated immediately beneath the posterior lamina of the muscle-fascia. It follows the curve of the sclerotic from the insertion of the recti to about 3 mm. from the optic nerve entrance, when it leaves the eyeball and blends with the posterior lamina of the muscle-fascia; the combined membrane may be traced backwards, enveloping the optic nerve-sheath loosely, approaching it as it nears the optic foramen, but never actually joining it. The interval between it and the nerve-sheath is called the *supravaginal lymph-space.* Tenon's capsule first comes into relation with the muscles at the point where they are left by their proper sheaths; it there invests their tendons, forms a small serous bursa on the anterior surface of each, and adheres to the sclerotic in the form of a line running around the globe, just anterior to the insertions of the four recti muscles. Between this line and the corneal border, the conjunctiva is separated from the sclerotic by the subconjunctival tissue, strengthened by a fine expansion of the muscle-fascia.

The inner surface of the capsule is smooth, and is only connected with the sclerotic by a loose, wide-meshed areolar tissue. This interval between the sclerotic and capsule, known as the **interfascial** or **Tenon's space,** is a lymph cavity, and permits free movements of the eyeball within the capsule.

Relation of Tenon's Capsule to the Oblique Muscles.—The capsule surrounds the posterior third of the inferior oblique and its tendon, running along its ocular surface till it meets the fascial band coming from the inferior rectus (see above), and forming a serous bursa on the superficial surface of the oblique near its insertion. The tendon of the superior oblique for about its last five millimetres is invested solely by Tenon's capsule; in front of this, as far as the trochlea, the tendon lies in a membranous tube derived from the muscle fascia, the inner lining of which is smooth, and may be considered as a prolongation of Tenon's capsule.

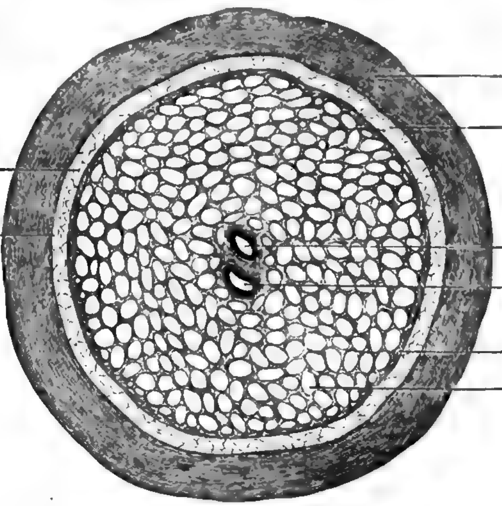
The Optic Nerve

The part of this nerve with which we have here to do lies within the orbit, extending from the optic foramen to the eyeball. Its course is somewhat S-shaped; thus, on entering the orbit, it describes a curve, with its convexity down and out, and then a second slighter curve, convex inwards. Finally, it runs straight forwards to the globe, which it enters to the inner side of its posterior pole.

In its passage through the optic canal the nerve is surrounded by a prolongation of the meninges. The dura mater splits at the optic foramen, part of it joining the periorbita, while the remainder continues to surround the nerve loosely as its outer or **dural sheath.** The nerve is closely enveloped by a vascular covering derived from the pia mater, named accordingly the **pial sheath.** The space between these two sheaths, known as the *intervaginal space*, is subdivided by a fine prolongation of the arachnoid (the **arachnoidal sheath**) into two parts, viz., an outer, narrow, *subdural*, and an inner, wider, *subarachnoid space*, communicating with the corresponding intracranial spaces. The arachnoidal sheath is connected with the sheath on each side of it by numerous fine processes which bridge across the intervening spaces. The pial sheath sends processes inwards, which form a frame-

work separating the bundles of nerve-fibres; between the enclosed nerve-fibres and each mesh of this framework there is a narrow interval occupied by lymph. The nerve-fibres are medullated, but have no primitive sheath. About fifteen or twenty millimetres behind the globe the central vessels enter, piercing obliquely the lower outer quadrant of the nerve, and then run forwards in its axis. They are

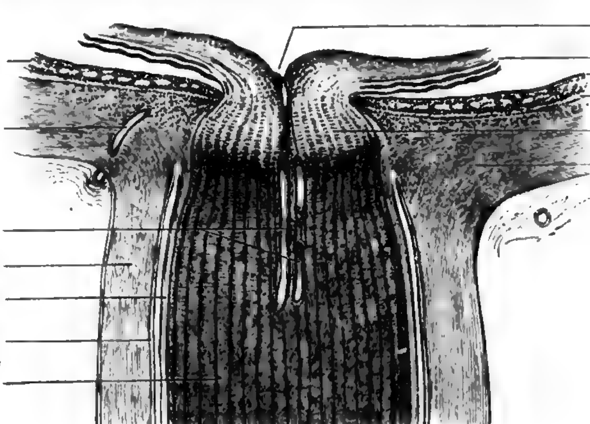
FIG 739.—TRANSVERSE SECTION THROUGH OPTIC NERVE, SHOWING THE RELATIONS OF ITS SHEATHS AND CONNECTIVE-TISSUE FRAMEWORK.



accompanied throughout by a special process of the pial sheath, which forms a fibrous cord in the centre of the nerve.

On reaching the eyeball, the dural sheath is joined by the arachnoid, and turns away from the nerve to be continued into the outer two-thirds of the sclerotic. Similarly the pial sheath also here leaves the nerve, its greater part running into the inner third of the sclerotic, while a few of its fibres join the chorioid; the inter-

FIG. 740.—LONGITUDINAL SECTION THROUGH TERMINATION OF OPTIC NERVE.



vaginal space consequently ends abruptly in the sclerotic around the nerve-entrance. In this locality the connective-tissue framework of the nerve becomes thicker and closer in its meshwork, and has been already alluded to as the **lamina cribrosa.** It is formed by processes passing out from the central fibrous cord at its termination and by processes passing inwards from the pial sheath, sclerotic, and chorioid. It does not pass straight across the nerve, but follows the curve of the surrounding sclerotic,

being therefore slightly convex backwards. The nerve-trunk here quickly becomes reduced to one-half its former diameter, the fibres losing their medullary sheath, and being continued henceforward as mere axis-cylinders. Apart from the consequent loss of bulk, this histological change may be readily recognised macroscopically in a longitudinal section of the nerve, its aspect here changing from opaque white to semi-translucent grey. The part of the nerve within the lamina cribrosa has already been seen in our ophthalmoscopic examination of the living eye.

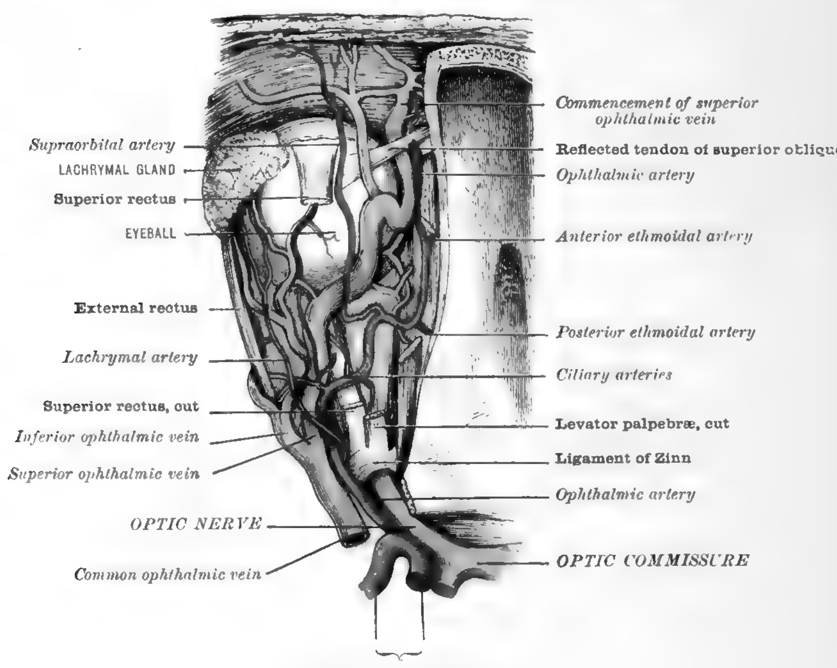
The optic nerve is mainly nourished by fine vessels derived from those of the pial sheath, which run into the substance of the nerve in the processes above mentioned. In front of the entrance of the central retinal artery this vessel aids to some extent in the blood-supply of the axial part of the nerve.

The Blood-vessels and Nerves of the Orbit

As these structures will be more particularly described in other sections of this work, a very short general account will suffice here.

Arteries.—The main blood-supply is afforded by the **ophthalmic artery,** a branch of the internal carotid, which gains the orbit through the optic canal, where it lies beneath and to the temporal side of the nerve. On entering the orbit it ascends, and passes obliquely over the optic nerve to the inner wall of the orbit; in this early part of its course it gives off most of its branches, which vary much in their manner of origin and also in their course. The arteries of the orbit are

Fig. 741.—The Blood-vessels of the Left Orbit, viewed from above.



remarkable for their tortuous course, for their delicate walls, and for their loose attachment to the surrounding tissues. The ophthalmic artery gives off special branches in the orbit to the lachrymal gland, the muscles, the retina (through the optic nerve), and the eyeball, as well as to the meninges, the ethmoidal cells, and the nasal mucous membrane. Twigs from all the different branches go to supply the fat, fasciæ, and ordinary nerves of the orbit. Branches which leave the orbit anteriorly ramify on the forehead and nose, and also go to the supply of the eyelids and the tear-passages. The ophthalmic artery has many anastomoses with branches of the external carotid. The contents of the orbit are also supplied in part by the **infraorbital artery,** a branch of the internal maxillary; in particular this artery

supplies part of the inferior rectus and inferior oblique muscles in the cavity, and also gives a branch to the lower eyelid.

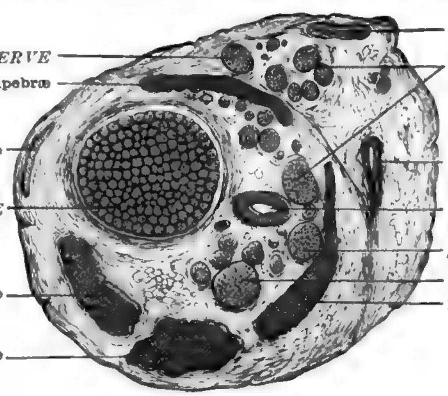
Veins.—Branches, corresponding generally to those of the artery, unite to form the **superior** and **inferior ophthalmic veins,** which ultimately, either separately or united into one trunk, pass through the superior orbital fissure and empty into the cavernous sinus. The inferior vein is connected with the pterygoid plexus by a branch which leaves the orbit by the inferior orbital fissure.

Nerves of the orbit.—These are **motor, sensory,** and **sympathetic,** and all enter the orbit by the superior orbital fissure, with the exception of one small sensory branch passing through the inferior orbital fissure. (The optic nerve has been already described, and is not included in this account.)

A. The **motor nerves** are the third, fourth, and sixth cranial.

1. The **third nerve** enters the orbit in two parts, an upper smaller, and a lower larger, division. The *upper division* gives off two branches: one supplies the superior rectus, entering its lower surface far back; the other branch goes to the levator palpebræ, entering its lower surface in its posterior third. The *lower division* divides into three branches, of which one supplies the inferior rectus, entering its upper surface far back, and another supplies the internal rectus, entering its inner surface a little behind its middle. The third branch of the lower division gives (1) the short root to the ciliary ganglion, and (2) one or more twigs to the inferior rectus,

Fig. 742.—Section through Contents of Right Orbit, 1–2 mm. in front of the Optic Foramen, viewed from behind. (After Lange.)



and the remainder of this branch then enters the lower surface of the inferior oblique muscle about its middle.

2. The **fourth nerve** supplies the superior oblique muscle, entering its upper surface about midway in its course.

3. The **sixth nerve** supplies the external rectus, entering its inner surface about the junction of the posterior and middle thirds of the muscle.

As regards the manner of termination of these motor nerves, it is found that in all the ocular muscles the nerve on its entrance breaks up into numerous bundles of fibres, which form first coarse and then fine plexuses, the latter ultimately sending off fine twigs supplying the muscle throughout with nerve-endings. The *posterior third* of these muscles is, however, comparatively ill supplied with both kinds of plexuses and with nerve-endings.

B. The **sensory nerves** are supplied by the first and second divisions of the fifth cranial nerve. The first division, or ophthalmic nerve, is entirely orbital; while the second, or maxillary, only sends a small branch to the orbit.

1. The **ophthalmic division of the fifth nerve** enters the orbit in three divisions, namely:—

(1) **Frontal,** splitting subsequently into *supratrochlear* and *supraorbital*, both passing out of the orbit. It is distributed to the corresponding upper eyelid, and the skin over the root of the nose, the forehead, and the hairy scalp as far back as the coronal suture on the same side. It also gives branches to the periosteum in this region, and to the frontal sinus.

(2) **Lachrymal,** supplying the lachrymal gland, anastomosing with a branch of the maxillary in the orbit, and finally piercing the upper eyelid. Outside the orbit it is distributed to the outer part of the upper lid, the conjunctiva at the external canthus, and the skin between this and the temporal region.

(3) **Naso-ciliary,** giving off—(*a*) a branch to the ciliary ganglion, constituting its long root; (*b*) two or three *long ciliary nerves;* and (c) the *infratrochlear,* passing out of the orbit. The nerve then leaves the orbit as the anterior ethmoidal nerve, re-entering the cranial cavity before being finally distributed to the nose. The infratrochlear branch supplies the eyelids and skin of the side of the nose near the inner canthus, the lachrymal sac, caruncle, and plica semilunaris. The anterior ethmoidal nerve, after its course in the cranial cavity, passes through an aperture in the front of the cribriform platé of the ethmoid bone, and is ultimately distributed to the nasal mucous membrane, and to the skin of the side and ridge of the nose near its tip.

2. The **maxillary division of the fifth nerve** gives a branch, called the **zygomatic nerve,** which passes into the orbit through the inferior orbital fissure, anastomoses with the lachrymal, and leaves the orbit in two divisions. These are distributed to the skin of the temple and of the prominent part of the cheek.

A few minute twigs from the spheno-palatine ganglion, and sometimes from the maxillary division of the fifth nerve, also pass through the inferior orbital fissure to supply the periorbita in this neighbourhood.

C. The **sympathetic nerves of the orbit** are mainly derived from the plexus on the internal carotid. With the exception of branches accompanying the ophthalmic artery, and of the distinct sympathetic root of the ciliary ganglion, they enter the orbit in the substance of the other nerve-cords. The connections between the ocular nerves and the carotid plexus are recognisable as fibres going to the third, sixth, and ophthalmic nerves; as a rule, the comparatively large twigs going to the sixth join it furthest back, and those to the third furthest forwards. Sympathetic connections with the fourth nerve are very doubtful. The special courses of the motor fibres to the dilator pupillæ have already been described.

The **ciliary ganglion** is situated between the optic nerve and external rectus far back in the orbit. Its three roots—motor, sensory, and sympathetic—have been already mentioned. Anteriorly, it gives off three to six small trunks, which subdivide to form the **short ciliary nerves,** about twenty in number, piercing the sclerotic around the optic nerve entrance.

The lymphatic system of the orbit.—Although there are no lymphatic *vessels* or *glands* in the orbit, the passage of lymph is nevertheless well provided for. We have already observed the lymph channels within, between, and outside the sheaths of the optic nerve, and have seen how these communicate anteriorly with the lymph channels of the eyeball, and posteriorly with the intracranial meningeal spaces. In addition, there are lymph-spaces around the blood-vessels, situated between the outer coat and the loose investment furnished by the muscle fascia. The nerves of the orbit (apart from the optic) are probably similarly surrounded by lymph-spaces. In the absence of lymphatic vessels it is difficult to trace the circulation thoroughly; much of the lymph from the orbital cavity is said to pass into the parotid nodes.

The Eyelids

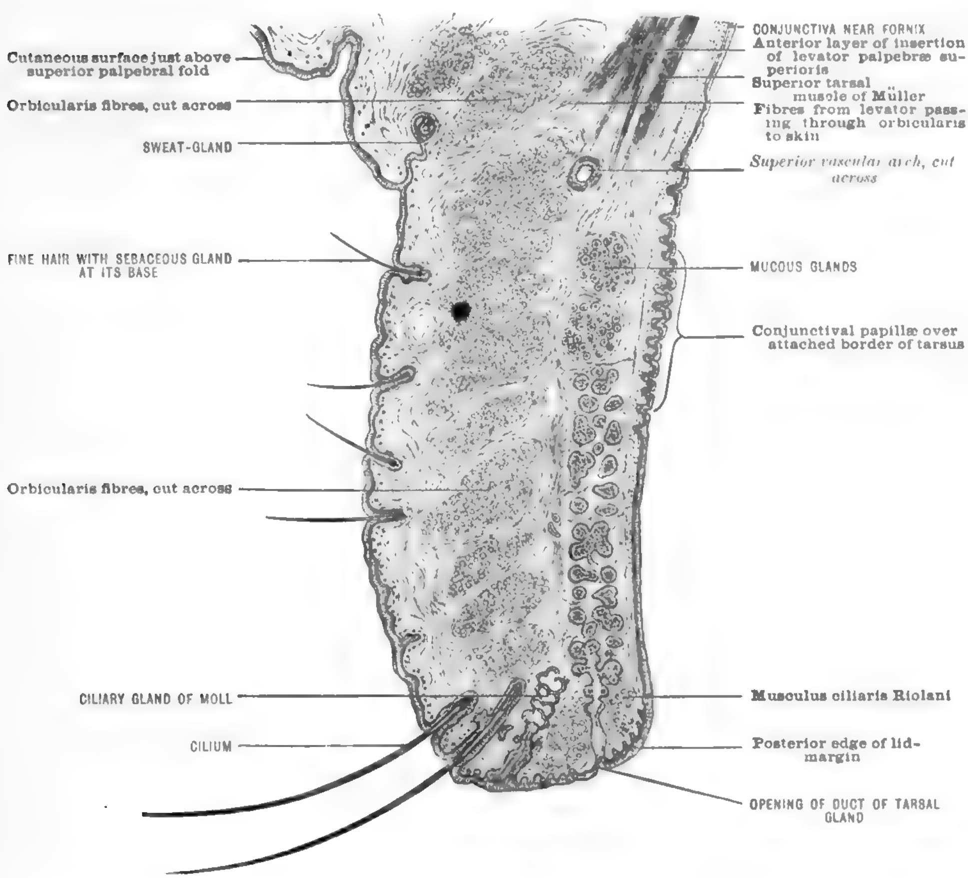
The cutaneous and conjunctival surfaces of the lids have already been examined, and the position of the tarsus has been indicated. We have now to ascertain the nature and relations of the tarsus, and describe the other tissues entering into the formation of the eyelids.

The skin here is thin, bearing fine hairs, and having small sebaceous and numerous small sweat-glands. Immediately beneath it is a loose subcutaneous tissue, destitute of fat, separating the skin from the palpebral part of the **orbicularis muscle.** The lid-fibres of this muscle arise from the inner palpebral ligament, and course over the whole upper and lower eyelids in a succession of arches, so as to meet again beyond the outer canthus; there they in part join one another, in part are inserted into the outer palpebral raphe. The muscular fibres are arranged in loose bundles, with spaces between them occupied by connective tissue; in the upper lid these connective-tissue fibres may be traced upwards and backwards into the fibrous expansion of the tendon of the levator palpebræ superioris. One strong

bundle of orbicularis fibres, called the **musculus ciliaris Riolani,** is found near the edge of the lid, in front of and behind the efferent ducts of the tarsal glands.

A **central connective tissue** separates the orbicularis muscle from the tarsus in the tarsal division of the lids. In the upper lid this is to be regarded as mainly the anterior or fibrous expansion of the tendon of the levator palpebræ, which sends connective-tissue septa between the bundles of the overlying orbicularis (as just mentioned) going to the skin. In the orbital part of this lid the central connective tissue includes also the palpebral fascia, lying here immediately beneath the orbicularis muscle; but this soon thins off and fades into the more deeply placed levator expansion. This latter is strengthened by an extension of the sheath of the superior rectus, by which this muscle is enabled to influence the elevation of the lid indirectly. In the lower lid the central connective tissue similarly consists

FIG. 743.—VERTICAL TRANSVERSE SECTION THROUGH THE UPPER EYELID. (After Waldeyer and Fuchs.)



of palpebral fascia, blended with a thin fibrous extension of the sheath of the inferior rectus. Immediately in front of each tarsus is a little loose connective tissue, which contains the large blood-vessels and nerves of the lids.

The **tarsus** of each lid is a stiff plate of close connective tissue, with its surfaces directed anteriorly and posteriorly; in its substance the tarsal glands are embedded. One tarsal border is free, viz., towards the edge of the lid, the other is attached; the former is straight, while the latter is convex, especially in the upper lid. The length of each tarsus is about twenty millimetres. Its breadth is greatest in the middle of the lid, and becomes gradually smaller towards each canthus, where the tarsi are joined to the outer and inner palpebral ligaments. The breadth of the upper tarsus (10 mm.) is about twice that of the lower. The thickness of each is greatest, and its texture closest, at the middle of its length, thin-

ning off towards the canthi and towards both borders. Into the superior anterior border of the upper tarsus the lower layer of the levator expansion is attached, consisting of smooth muscle-fibres constituting the **superior tarsal muscle** of Müller. In like manner, at the inferior border of the lower tarsus, bundles of smooth muscle-fibre are inserted (the **inferior tarsal muscle** of Müller), developed in what has been regarded as part of the extension of the sheath of the inferior rectus.

The **palpebral conjunctiva** is firmly adherent to the back of the tarsus; but in the orbital part of the lid loose subconjunctival tissue intervenes between it and Müller's tarsal muscle. Adenoid tissue occurs in the substance of the conjunctiva, especially in its orbital division. Near the upper fornix, the conjunctiva receives expansions of the tendon of the levator palpebræ and of the sheath of the superior rectus, and, at the lower fornix, of the sheath of the inferior rectus. The surface of the tarsal conjunctiva shows small elevations or papillæ everywhere; but these are particularly well marked over the attached border of the tarsus.

Glands of the eyelids.—From its manner of formation the eyelid may be regarded as consisting of two thicknesses of skin, the inner (or posterior) having been doubled back upon the outer at the edge of the lid; thus the cuticle and corium of the skin proper are represented respectively by the conjunctiva and tarsus of the inner thickness. At the free border of the lid, accordingly, we find glands corresponding to the sebaceous and sweat-glands of the skin, viz., large sebaceous glands of the cilia (Zeiss's glands) and the ciliary glands of Moll, which are modified sweat-glands. Again, in the inner skin-thickness of the lid, the tarsal (Meibomian) glands are sebaceous. Acino-tubular mucous glands occur at the attached border of the tarsus (Krause's or Waldeyer's glands), and similar glands also occur at the fornix, and are especially abundant near the outer canthus of the upper lid, close to the efferent ducts of the lachrymal gland; from their structure and the character of their secretion, these acinous or acino-tubular glands have been termed by Henle 'accessory lachrymal glands.' Other simple tubular glands (Henle), formed merely by the depressions between the papillæ, are best developed in the inner and outer fourths of the tarsal conjunctiva of both lids.

Blood-vessels.—The arteries run in the central connective tissue of the lids, mainly in the form of arches near the borders of the tarsus, from which twigs go to the different palpebral tissues. They are supplied by the lachrymal and palpebral branches of the ophthalmic, and by small branches derived from the temporal artery. The veins are more numerous and larger than the arteries, and form a close plexus beneath each fornix. They empty themselves into the veins of the face at the inner, and into the orbital veins at the outer, canthus.

The **lymphatic vessels of the lids** are numerous, and are principally situated in the conjunctiva. Lymph-spaces also surround the follicles of the tarsal glands. The palpebral lymphatic vessels mainly pass through the parotid nodes; but, sometimes at least, those from the inner half of the lower lid go to the submaxillary lymphatic nodes.

Nerves.—(*a*) **Sensory.** The upper lid is chiefly supplied by branches of the supraorbital and supratrochlear nerves, the lower lid by one or two branches of the infraorbital. At the inner canthus the infratrochlear nerve also aids in the supply, and, at the outer canthus, the lachrymal. (*b*) **Motor.** The palpebral part of the orbicularis is supplied by branches of the facial nerve, which mainly enter it near the outer canthus. Müller's tarsal muscles are supplied by the sympathetic nervous system.

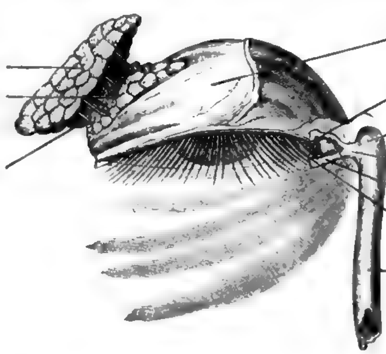
The **inner palpebral ligament,** or **tendo oculi,** has been referred to previously. Arising from the frontal process of the maxilla, it extends outwards over the front wall of the lachrymal sac, bends round the outer wall of the sac, and then passes backwards to the posterior crest on the lachrymal bone. It is thus U-shaped, having its limbs anterior and posterior, embracing the lachrymal sac; the anterior limb lies immediately beneath the skin. and is visible in the living. The palpebral fibres of the orbicularis are inserted into the outer surface of both limbs, those attached to the posterior limb constituting **Horner's muscle.** The **outer palpebral raphe** is merely a stronger development of connective tissue in the orbicularis. Both ligaments are connected with the tarsi as already mentioned.

THE LACHRYMAL APPARATUS

The tears are secreted by an acinous gland, and flow through fine ducts to the upper outer part of the conjunctival sac, whence they are drained off through the puncta, pass along the canaliculi into the lachrymal sac, and ultimately run down the nasal duct to gain the inferior meatus of the nose.

The **lachrymal gland** is situated near the front of the outer part of the roof of the orbit, lying in a depression in the orbital plate of the frontal bone. It consists of two very unequal parts, one placed above and the other beneath the tendinous expansion of the levator palpebræ superioris, but small gaps in the expansion permit of connections between these two parts of the gland. The upper and larger subdivision (*superior lachrymal gland*) is a firm elongated body, about the size of a small almond; it has a greyish-red colour, and is made up of closely aggregated lobules. The upper surface (next the orbital roof) is convex, and its lower surface is slightly concave. Anteriorly, the gland almost reaches the upper orbital margin, and it extends backwards for approximately one-fourth the depth of the orbit, measuring about twelve millimetres in this direction. The outer border of the gland descends to near the insertion of the fascial expansion of the external rectus, while its inner border almost reaches the outer edge of the superior rectus; its transverse measurement is about twenty millimetres. It is enveloped in a capsule, which is slung by strong fibrous bands passing to its inner border from the orbital margin (suspensory ligament of the gland).

Fig. 744.—Lachrymal Apparatus. (After Schwalbe.)



The lower subdivision of the gland (*inferior lachrymal gland*) is composed of loosely applied lobules, and lies immediately over the outer third of the upper conjunctival fornix, reaching outwards as far as the external canthus.

Each subdivision of the gland possesses several **excretory ducts,** which all open on the outer part of the upper fornix conjunctivæ, about four millimetres above the upper border of the tarsus. Those of the superior gland, three or four in number, pass between the lobules of the lower gland; the outermost duct is the largest, and opens at the level of the external canthus. The ducts of the inferior gland in part discharge themselves into those of the upper, but there are also several fine ducts from this subdivision that run an independent course.

Near the inner canthus are the two **puncta lachrymalia,** upper and lower, each situated at the summit of its papilla. The top of each papilla curves backwards towards the conjunctival sac, so that the puncta are well adapted for their function of draining off any fluid collecting there.

The **ductus (canaliculi) lachrymales** extend from the puncta to the lachrymal sac. The lumen at the punctum is horizontally oval, from its lips being slightly compressed antero-posteriorly; the lumen of the lower punctum is somewhat larger than that of the upper. As the lower papilla is a little further from the inner canthus than the upper, the corresponding canaliculus is longer.

On tracing either ductus from its origin, we find that at first it runs nearly vertically for a short distance, then bends sharply towards the nose, and finally courses more or less horizontally, converging slightly towards its fellow, and not infrequently joining it before opening into the sac. The calibre varies considerably

in this course, being narrowest a short distance from the punctum, and widest at the bend, from which point it again narrows very gradually as it nears the sac. The wall of the ductus consists mainly of elastic and white fibrous tissue, lined internally by epithelium, and covered externally by striated muscle (part of the orbicularis). The muscle-fibres run parallel to the ductus in the horizontal part of its course; but they are placed, some in front and some behind, around the vertical part, acting here as a kind of sphincter. Just before their termination, the ducts pierce the periosteal thickening that constitutes the posterior limb of the inner palpebral ligament.

The **lachrymal sac** lies in a depression in the bone at the inner angle of the orbit (the lachrymal fossa). It is vertically elongated, and narrows at its upper and lower ends; the upper extremity or *fundus* is closed, while the lower is continuous directly with the nasal duct. Laterally, the sac is somewhat compressed, so that its antero-posterior is greater than its transverse diameter. The ducts, either separately or by a short common tube, open into a bulging on the outer surface of the sac near the fundus. As has previously been mentioned, the sac is surrounded by periosteum, but between this and the mucous membrane forming the true sac-wall there is a loose connective tissue, so that the cavity is capable of considerable distension. The relations of the inner palpebral ligament have already been described; it is to be noted that the fundus of the sac extends above this ligament.

The **naso-lachrymal duct** reaches from the lower end of the sac to the top of the inferior meatus of the nose, opening into the latter just beneath the adherent border of the inferior nasal concha. Traced from above, its main direction is downwards, but it has also a slight inclination backwards and outwards. It lies in a bony canal, whose periosteum forms its outer covering. Between this and the mucous membrane of the duct there is a little intermediate tissue, in which run veins of considerable size connected with the plexus of the inferior concha. The duct does not usually open directly into the nasal cavity at the lower end of the bony canal, but pierces the nasal mucous membrane very obliquely, so that a *flap* of mucous membrane covers the lower border of the opening in the bone, upon which flap the tears first trickle after escaping from the duct proper.

The sac and naso-lachrymal duct together constitute the **lachrymal canal,** lined throughout by a continuous mucous membrane. This membrane presents *folds* in some situations, especially near the opening of the canaliculi, at the junction of the sac and duct, and at the lower end of the duct. That at the top of the duct is the most important, as it sometimes interferes with the proper flow of tears out of the sac. The total length of the lachrymal canal is roughly twenty-four millimetres, half of this being sac, and half naso-lachrymal duct. If, however, we reckon as duct the oblique passage through the nasal mucous membrane, this measurement may occasionally be increased by eight or ten millimetres. The lachrymal sac, when distended, measures about six millimetres from before backwards, by four millimetres transversely. The naso-lachrymal duct is practically circular, and has a diameter of about three millimetres, rather less at its junction with the sac, where we find the narrowest part of the whole lachrymal canal.

THE EAR

Originally Written by Arthur Hensman, F.R.C.S., and Arthur Robinson, M.D., M.R.C.S. Revised and Largely Rewritten

By ABRAM T. KERR, B.S., M.D.

PROFESSOR OF ANATOMY IN THE CORNELL UNIVERSITY MEDICAL COLLEGE

The **auditory organ,** or ear, is divided into three parts—external, middle, and internal.

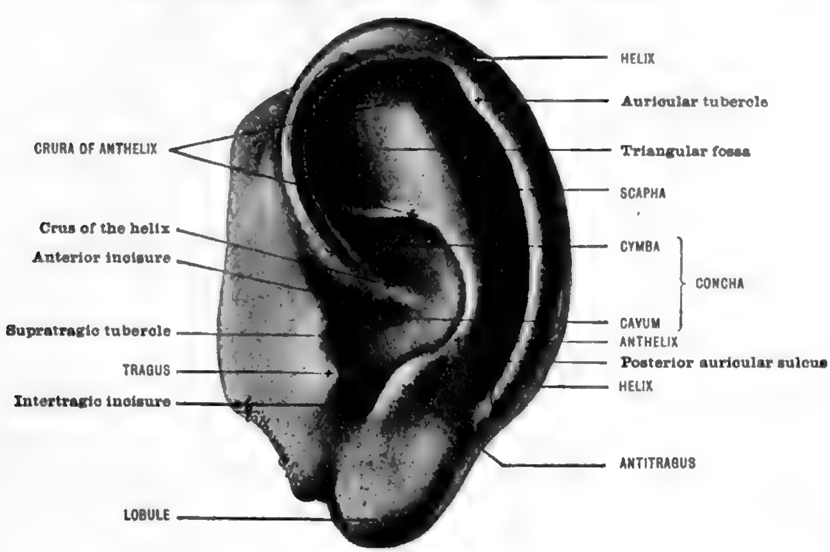
THE EXTERNAL EAR

The **external ear** consists of the auricle attached to the side of the head, and the external acoustic (auditory) meatus leading from it to the middle ear (fig. 747).

THE AURICLE

The **auricle,** or pinna, presents a lateral and a medial surface. The lateral surface is irregularly concave (fig. 745), the deepest part of the concavity, the **concha,** being partially divided by an oblique ridge, the **crus of the helix,** into a superior

Fig. 745.—Lateral Surface of the Left Auricle.



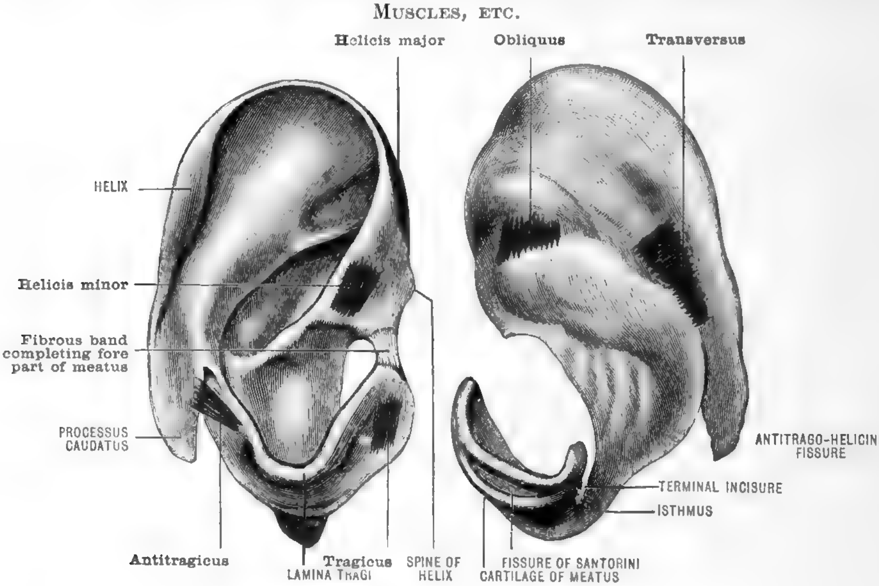
part, the **cymba conchæ,** and a larger inferior part, the **cavum conchæ.** This latter is directly continuous with the acoustic meatus, and is bounded ventrally by a prominent process, the **tragus,** which projects dorsally and overhangs the entrance to the meatus. The tragus, which has a small tubercle on it superiorly, the **supratragic tubercle,** is separated from the crus of the helix by a well-marked depression, the **anterior incisure.** Bounding the cavum conchæ dorsally and inferiorly is a projection, the **antitragus,** which is situated opposite, but inferior, to the tragus, and between the two is a deep notch, the **intertragic incisure.** Bounding the concha dorsally and superiorly is a prominent semicircular ridge, the **anthelix,** ending in-

feriorly in the antitragus, from which it is separated by a slight depression, the **posterior auricular sulcus.** The anthelix divides superiorly into two ridges, the **crura of the anthelix,** and between these is a shallow depression, the **triangular fossa.** The superior and dorsal margin of the auricle is rolled in towards the concha, thus producing a prominent inturned rim, the **helix,** continuous anteriorly with the crus of the helix, and inferiorly with the **lobule,** and also an elongated depression, the **scapha** (scaphoid fossa), which separates the helix and the anthelix. Superiorly and dorsally the free margin of the helix frequently presents a slight projection, the **auricular tubercle** (tubercle of Darwin). Upon the medial surface of the auricle the depressions of the lateral surface are represented by the **eminence of the concha,** the **eminence of the scapha,** and the **eminence of the triangular fossa;** and the elevations by the **fossa of the anthelix, transverse sulcus of the anthelix,** and the **sulcus of the crus of the helix.** The attachment of approximately one-third of the medial surface covers up the two latter depressions. The **cephalo-auricular angle,** which is formed between the dorsal free part and the side of the head, averages 20 to 30 degrees.

Structure of the Auricle

The characteristic features of the auricle just described are mainly produced by a folded yellow elastic cartilage, the **auricular cartilage,** which, in addition to the elevations and depressions already noted, presents the following additional features.

Fig. 746.—Lateral and Medial Surface of the Cartilage of the Right Pinna and its Muscles, etc.



Projecting anteriorly from the helix near the crus is a small tubercle, **spine of the helix** (fig. 746); a part of the helix, **cauda helicis,** is separated inferiorly from the antitragus by the deep **antitrago-helicine fissure;** and another deep fissure, the **terminal incisure,** separates the cartilage of the auricle from that of the meatus, leaving only a narrow strip, the **isthmus,** connecting the two. The cartilage of the tragus, the **lamina tragi,** is separated from that of the auricle and is attached to the lateral edge of the cartilage of the meatus.

The **skin of the auricle** closely follows the irregularities of the cartilage. It is tightly bound to the perichondrium of the lateral surface by the subcutaneous areolar tissue, but much more loosely attached to the medial surface, and in the subcutaneous tissue there is little fat except in the lobule, which is made up almost entirely of fat and tough fibrous tissue. **Hairs** are abundant but rudimentary, except in the region of the tragus and antitragus, where they may be large and long, particularly in males and in the aged. **Sebaceous glands** are found on both surfaces, and are especially well developed in the concha and triangular fossa, but **sudoriferous glands** are few and scattered.

Ligaments and muscles.—The auricle is attached to the side of the head by the skin, by the continuity of its cartilage with that of the acoustic meatus, and by certain extrinsic ligaments and muscles. Three ligaments may be distinguished in the connective tissue:—The **anterior ligament,** stretching from the zygoma to the helix and tragus; the **superior ligament,** from the superior margin of the bony external acoustic meatus to the spine of the helix; and the **posterior ligament,** from the mastoid process to the eminence of the concha. There are also three extrinsic muscles, the anterior, superior, and posterior auricular (see p. 333, fig. 306). Six intrinsic muscles are distinguished. These are poorly marked in man and vary much in development. Upon the lateral surface (fig. 746) the **helicis major** stretches from the spine of the helix to the ventral superior margin of the helix; the **helicis minor** overlies the crus helicis; the **tragicus** runs vertically upon the tragus; and the **antitragicus** stretches from the antitragus to the cauda helicis. Upon the medial surface (fig. 746) the **transversus auriculæ** stretches between the eminences of concha and scapha, and the **obliquus** between the eminences of the concha and the triangular fossa.

Vessels and Nerves

The **arteries** are the auricular branch of the posterior auricular and the anterior auricular branches of the superficial temporal (pp. 526 and 527). The **veins** are the anterior auricular vein of the posterior facial (temporal) and the auricular branches of the posterior auricular (pp. 648 and 649). The latter sometimes join the transverse (lateral) sinus through the mastoid emissary vein. The **lymphatics** empty into the anterior and posterior auricular lymph-nodes (p. 707). The sensory **nerves** of the auricle are the branches of the great auricular, small occipital (p. 913, fig. 708), and auriculo-temporal (p. 971, fig. 708). The muscles are supplied by the posterior auricular branch of the facial (p. 977, fig. 705).

Variations

There are many variations in the size, shape, and conformation of the auricle and in the cephalo-auricular angle. These are associated not only with differences in sex, age, and race, but are also found in individuals of the same family.

THE EXTERNAL ACOUSTIC MEATUS

The **external acoustic (auditory) meatus** extends medially and somewhat ventrally from the concha to the tympanic membrane (fig. 747). It is about twenty-five mm. (1 in.) long, and, owing to the obliquity of the tympanic membrane, its ventral and inferior wall is slightly longer than the dorsal and superior. It consists of a lateral **cartilaginous** and a medial **osseous portion.** The canal describes an S-shaped curve in both horizontal and vertical directions, and is convex ventrally and inferiorly towards its auricular end, and concave ventrally and inferiorly towards its tympanic end. The irregularly elliptical lumen has its long axis vertical at the auricular, but nearly horizontal at its tympanic end, and it is constricted at about its centre, and also near the tympanum.

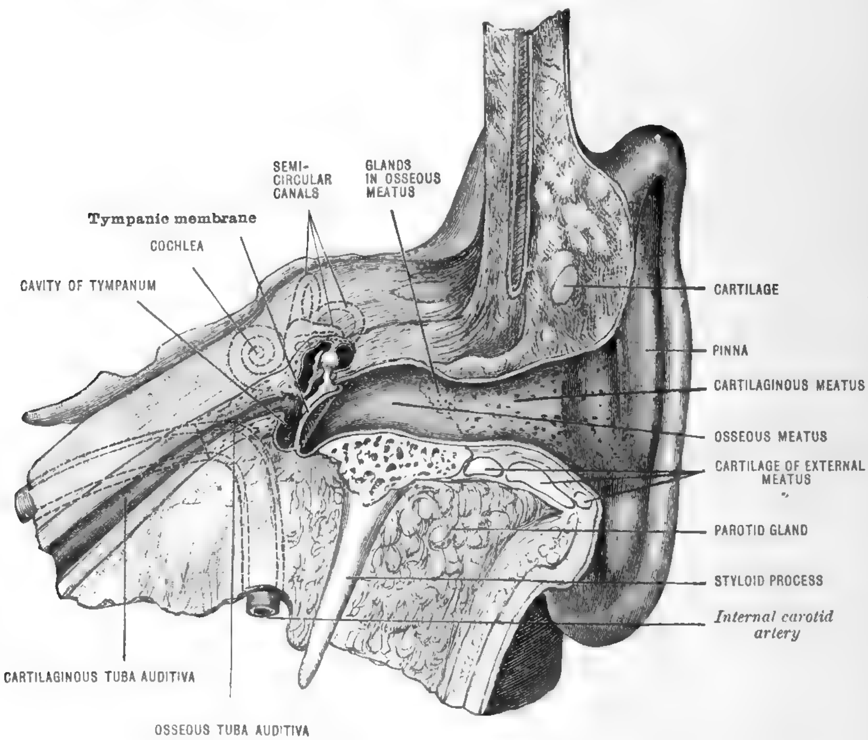
Relations.—The *anterior wall* is in relation with the condyle of the mandible medially, and with the parotid gland laterally; the *inferior wall* is closely bound to the parotid gland; and the *posterior wall* of the bony part is separated by only a thin plate of bone from the mastoid cells. The *superior wall* is separated at its medial end by a thin plate of bone from the epitympanic recess, and laterally a thicker layer of bone separates it from the cranial cavity.

Structure of the meatus.—The walls of the meatus are formed laterally of fibro-cartilage and medially of bone. The cartilage is folded upon itself to form a groove, the deficient and dorsal part of which is completed by dense connective tissue, the groove being thus converted into a canal. Medially, the cartilage forms about one-third of the circumference; laterally, two-thirds. Two fissures or *incisures* (*incisures of Santorini*) usually occur in its anterior wall (fig. 746). Laterally the cartilage is directly continuous with the cartilage of the auricle and medially it is firmly connected with the lateral lip of the osseous portion. The **osseous portion** forms slightly more than half the canal, and is formed by the tympanic portion of the temporal bone; it is described in connection with that bone (p. 63).

The **skin of the meatus** forms a continuous covering for the canal and tympanic membrane. It is thick in the cartilaginous, but very thin in the bony, part of the meatus, especially near the tympanic end, where it is tightly bound to the periosteum.

In the cartilaginous meatus it is supplied with numerous fine hairs and sebaceous glands, neither of which are found in the bony meatus, and tubular **ceruminous glands,** which secrete the **cerumen** (ear wax), form a nearly continuous layer throughout the cartilaginous, but occur on only a small part of the dorsal and superior wall

Fig. 747.—Section of the Middle and External Ear.



of the bony, meatus. The openings of their ducts appear as dark points to the naked eye (fig. 747).

The **arteries** are branches from the posterior auricular, superficial temporal, and deep auricular (pp. 526 and 529). The **veins** and **lymphatics** connect with those of the auricle and empty similarly. The **nerves** are branches from the auriculo-temporal and the auricular ramus of the vagus.

THE MIDDLE EAR

The **middle ear** is completely separated from the external ear by the tympanic membrane, which is stretched obliquely across the medial end of the external acoustic meatus.

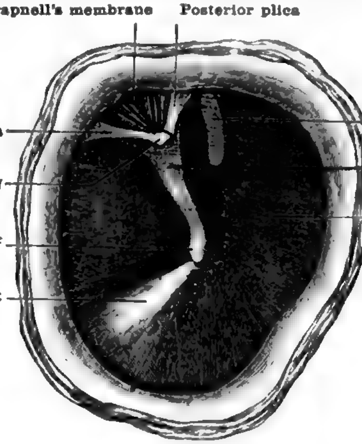
The **tympanic membrane** is elliptical, its long axis measuring 9 to 10 mm., its short axis, 8 to 9 mm. It slopes medially from the superior and dorsal to the inferior and ventral wall of the meatus, forming, as a rule, with the superior wall, an angle of 140 degrees (von Tröltsch). It varies, however, greatly in form, size, and obliquity. The semitransparent membrane, which sometimes has a reddish tinge, is drawn medially and made funnel-shape by the manubrium of the malleus, but the walls of the funnel bulge towards the meatus (fig. 750). The most depressed point, the **umbo,** is slightly inferior and dorsal to the centre of the membrane, and corresponds to the tip of the manubrium (fig. 748), and from it a whitish streak, the **malleolar stria,** caused by the manubrium shining through, passes superiorly towards the circumference. At the superior end of the stria a slight projection, the **malleolar prominence,** is formed by the lateral process of the malleus, and from it two folds, the **anterior and posterior plicæ,** stretch to the extremities of the tympanic sulcus (fig. 748). The small triangular area of the membrane bounded by the

plicæ, the **pars flaccida,** or Shrapnell's membrane, is thin and flaccid, and is attached directly to the petrous bone in the tympanic notch (notch of Rivinus). The larger part of the tympanic membrane, the **pars tensa,** is inferior to the plicæ and is tightly stretched. Its thickened margin, the **limbus,** is attached by a fibro-cartilaginous **annulus** to the tympanic sulcus, and at the spines of the tympanic ring is continuous with the plicæ.

Structure of the tympanic membrane.—The tympanic membrane is about 1 mm. thick, and consists of four layers. The lateral **cutaneous layer** is very thick, and is a continuation of the cutaneous layer of the external acoustic meatus. Next to it is a **radiate fibrous layer,** composed of connective tissue, the fibres of which are attached to the manubrium of the malleus and radiate from it. The **circular fibrous layer,** which has its fibres arranged concentrically and is especially thick at the circumference, is closely bound to the radiate layer, and, finally, the **mucous layer,** which is a continuation of the mucosa of the tympanic cavity, covers the medial surface of the membrane smoothly, except where the manubrium of the malleus causes a projection. The fibrous layers are attached to the fibro-cartilaginous ring and are lacking in the pars flaccida.

The **tympanic cavity** is an air-space lined with mucous membrane and situated between the external and internal ears (fig. 747). It measures about 15 mm. in both ventro-dorsal and vertical directions, and its width varies from 2 mm. to 4 mm. or more, being narrowest at the centre and wider superiorly than inferiorly. It pre-

Fig. 748.—Lateral Surface of the Left Membrana Tympani. (Enlarged from life.)

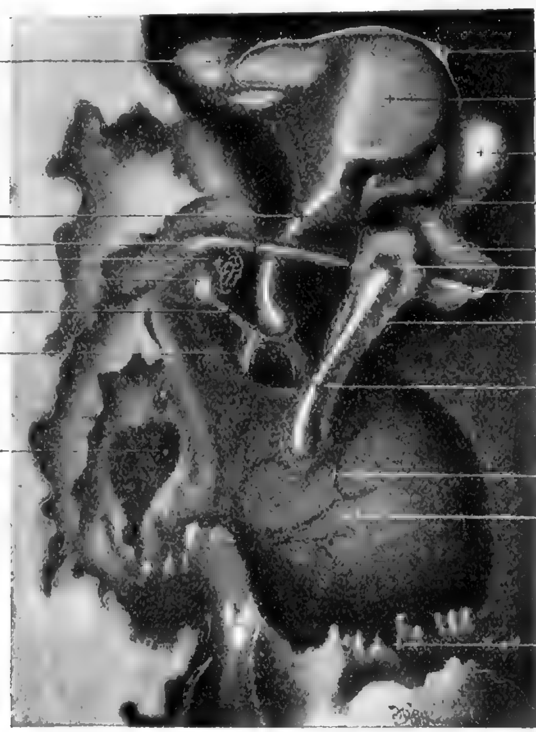


sents for examination six walls, each of which is named from the principal structure which is in relation with it and also from its position. These walls have been partially described in connection with the temporal bone (pp. 66, 67), so that it will be necessary here merely to name the various parts.

The **tegmental (superior) wall** is roofed by the thin *tegmen tympani* (fig. 751). At its lateral edge, in the infant, is the *petro-squamous suture,* and in this situation an occasional slight deficiency of the roof may persist. The **jugular wall** or **floor** separates the cavity from the jugular fossa, and presents a prominence corresponding to the base of the styloid process, and numerous depressions. Upon the **mastoid (posterior) wall** may be noted inferiorly, additional *tympanic cellulæ* (fig. 749), and above these is the *pyramidal eminence* with the *tendon of the stapedius muscle* emerging from its apex, and superiorly the *chorda tympani nerve,* issuing from its canal. Superior to these are a depression, the *posterior sinus,* a *fossa,* which marks the attachment of the posterior ligament of the incus, and the opening into the tympanic (mastoid) antrum. The *tympanic (mastoid) antrum* leads posteriorly and inferiorly into the *mastoid air-cells,* which are described on pp. 61, 65, 67, and anteriorly connects with the superior part of the tympanic cavity, *epitympanic recess,* or attic (fig. 751), which extends inferiorly to the level of the tympanic membrane and superiorly to the tegmen tympani. The *prominence of the facial (Fallopian) canal* and the *prominence of the lateral semicircular canal* are seen superiorly, partly upon the posterior, but mainly upon the medial wall. The **car-**

otid (anterior) wall presents superiorly the *tensor tympani muscle* in its canal, and the opening of the *tuba auditiva* (Eustachian tube) (fig. 751). Inferiorly, a thin, bony wall, covered with tympanic cellulæ and pierced by the carotico-tympanic nerves, separates the tympanic cavity from the carotid canal. The **membranous (lateral) wall** is formed mainly by the tympanic membrane, with the small rim of bone to which it is attached, but superiorly the lateral wall of the epitympanic recess is formed by bone. The **labyrinth (medial) wall** (fig. 749) presents ventrally the *promontory*, with the *tympanic plexus* (Jacobson's nerve) lodged in grooves upon its surface. Inferior and posterior to the promontory is a depression or fossula at the bottom of which is the *cochlear fenestra* (fenestra rotunda), closed by the *secondary tympanic membrane*, and posterior to the promontory is a smooth projection, the *subiculum of the promontory*, which forms the inferior border of a rather deep depression known as the *tympanic sinus*. Superiorly is the *cochleariform process*, and superiorly and posteriorly are a depression or fossula leading to the *vestibular fenestra* (*fenestra ovalis*),

FIG. 749.—THE LABYRINTH (MEDIAL) WALL OF THE RIGHT TYMPANUM WITH THE TYMPANIC OSSICLES IN POSITION.



which is closed by the base of the stapes, the prominence of the facial (Fallopian) canal, and the prominence of the lateral semicircular canal.

The tympanic cavity contains three small movable bones, joined together and to the walls of the cavity, and having attached to them special muscles and ligaments. These auditory ossicles form a chain across the tympanic cavity, connecting the tympanic membrane and the vestibular (oval) fenestra. They are the **malleus,** the **incus,** and the **stapes,** and are described on p. 69.

Articulations of the ossicles.—The manubrium and lateral process of the malleus are imbedded in the tympanic membrane, and an irregularly elliptical articular surface on the posterior side of the head of the malleus is bound to the body of the incus by a thin capsular ligament, forming a diarthrodial joint, the **incudo-malleolar articulation.** From the inner surface of the capsular ligament, a wedge-shaped rim projects into the joint cavity and incompletely divides it. The long crus of the incus is arranged parallel but dorsal and medial to the manubrium of the malleus (figs. 749 and 751), and ends dorsally and superiorly to the tip of the manubrium in the lenticular process. The convex extremity of this fits into the concavity on the head of the stapes, to form a diarthrodial joint, the **incudo-stapedial articulation.** From its articulation with the incus the stapes passes almost horizontally across the tympanic cavity to its junction

with the medial wall. The cartilage-covered edge of the base is bound to the cartilage-covered rim of the vestibular (oval) fenestra by the annular ligament of the base of the stapes, thus forming the **tympano-stapedial syndesmosis.**

Ligaments of the ossicles.—In addition to the attachment of the manubrium of the malleus and the base of the stapes to the walls of the tympanic cavity, the bones have additional ligamentous attachments. The **superior malleolar ligament** runs almost vertically from the superior wall of the epitympanic recess to the head of the malleus (fig. 750). The **anterior malleolar ligament** extends from the angular spine of the sphenoid bone through the petro-tympanic (Glaserian) fissure to the anterior or long process of the malleus, which it surrounds, and is inserted with it into the neck of the malleus. The **lateral malleolar ligament** is short and thick, and runs from the margins of the tympanic notch (notch of Rivinus) to the neck of the malleus (fig. 750). The **posterior ligament of the incus** passes from the fossa on the posterior tympanic wall to the crus brevis of the incus (fig. 751). The **superior ligament** of the incus is little more than mucous membrane; it runs from the tympanic roof to the body of the incus.

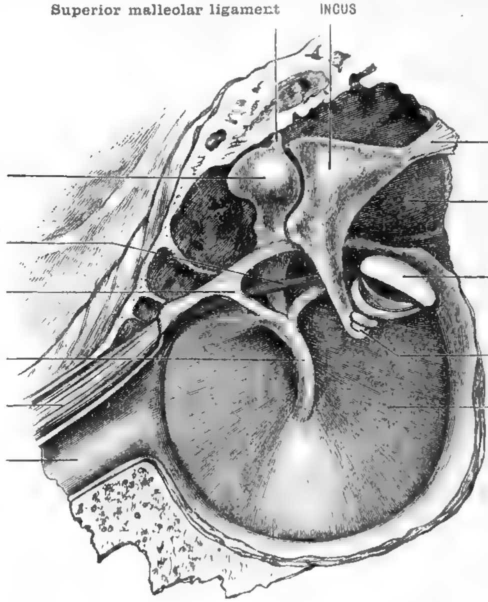
Fig. 750.—The Tympanic Cavity, Anterior Wall Removed.

Muscles of the ossicles.—Each of the muscles of the ossicles is contained in a bony canal. The **tensor tympani** is a pinniform muscle about 2 cm. long. It arises from the cartilaginous part of the tuba auditiva (Eustachian tube), from the adjacent part of the great wing of the sphenoid, and from the bony walls of the semicanal which encloses it. It ends in a round tendon which turns almost at right angles over the cochleariform process and passes laterally across the tympanic cavity to be attached to the manubrium of the malleus near the neck. It draws the manubrium medially and tightens the tympanic membrane, and is supplied by the motor division of the fifth cranial nerve, through the tensor tympani branch from the otic ganglion. The **stapedius** arises from the inside of the hollow pyramidal eminence, the apex of which is pierced by its tendon, which then turns inferiorly and is inserted on the posterior surface of the neck of the stapes. It draws laterally the ventral border of the base of the stapes and is supplied by the facial nerve.

The **tympanic mucous membrane** forms a complete covering for the walls and

contents of the tympanic cavity, and is continuous anteriorly with the mucosa of the tuba auditiva (Eustachian tube) and posteriorly with that of the tympanic (mastoid) antrum and mastoid cells. It is a thin, transparent, vascular membrane intimately united to the periosteum. As it passes from the walls to the contents of the tympanic cavity, besides covering the ligaments of the malleus and the incus and the tendons of the tensor tympani and stapedius muscles, it forms a number of special folds and pouches. The **anterior malleolar fold** is reflected from the tympanic membrane over the anterior process and ligament of the malleus and the adjacent part of the chorda tympani, and the **posterior malleolar fold,** stretching between the manubrium and the posterior tympanic wall, surrounds the lateral ligament of the malleus and the posterior part of the chorda tympani. Each of these folds presents inferiorly a concave free border, and between them and the tympanic membrane are two blind pouches, the **anterior and posterior malleolar recesses** or pouches of Tröltsch. Connected with the posterior recess is a third cul-de-sac, the **superior recess** of the tympanic membrane, or pouch of Prussak, situated between the pars flaccida of the tympanic membrane and the neck of the malleus. Its floor, which is formed by the lateral process of the malleus, is lower than its outlet and, therefore, it may serve

Fig. 751.—Medial Surface of Right Membrana Tympani. (Enlarged.)



as a pocket in which pus or other fluid may accumulate. A somewhat variable fold of mucosa, the **plica incudis,** passes from the roof of the tympanic cavity to the body and short process of the incus. The body and short process of the incus, the head of the malleus, and this fold incompletely separate off a lateral **cupular portion** of the epitympanic recess, and a **stapedial fold** stretches from the posterior wall of the tympanic cavity and surrounds the stapes, including the obturator membrane, which stretches between its crura. Other inconstant folds have been described. The mucosa of the tympanic cavity, except over the tympanic membrane, promontory, and ossicles, is covered by a columnar ciliated epithelium.

Vessels and nerves.—The **arteries of the tympanic cavity** are the anterior tympanic from the internal maxillary artery (p. 529, fig. 413), the stylo-mastoid from the posterior auricular artery (p. 526), the superficial petrosal from the middle meningeal artery (p. 529), the inferior tympanic from the ascending pharyngeal (p. 518, fig. 408), and the carotico-tympanic branch from the internal carotid. The **veins** empty into the superior petrosal sinus and into the posterior facial (temporo-maxillary) vein (p. 648). The **nerves** are the tympanic plexus formed by the tympanic branch of the glosso-pharyngeal (p. 981), and the inferior and superior carotico-tympanic nerves from the internal carotid plexus of the sympathetic (p. 1005). The small superficial petrosal nerve takes its origin from the tympanic plexus, and the chorda tympani crosses the tympanic cavity from the dorsal to the ventral wall (p. 977, figs. 704 and 751).

The **tuba auditiva** (Eustachian tube) (fig. 747) extends from the carotid (anterior) wall of the tympanic cavity inferiorly, medially, and ventrally to the pharynx. It is about 37 mm. (1·5 in.) long, and throughout one-third of its length has a bony wall, that of the other two-thirds being cartilaginous. The **osseous part** (see p. 66) begins at the **tympanic ostium** on the anterior wall of the tympanic cavity. It is in relation medially and inferiorly with the carotid canal, and gradually contracts to its irregular medial extremity, which is the narrowest point in the tube, and is termed the **isthmus.** The **cartilaginous part** is firmly attached to the osseous and lies in a sulcus at the base of the angular spine of the sphenoid bone. It gradually dilates in its passage to the lateral wall of the pharynx, where its opening, **pharyngeal ostium,** is just posterior to the inferior nasal concha (turbinated bone). The walls of the cartilaginous part are formed by a cartilaginous plate which is folded so as to form a trough-like structure, consisting of a medial and a lateral **lamina,** completed inferiorly by a **membranous lamina** formed of connective tissue. A small portion of the lumen in the superior part of the cartilaginous tube remains permanently open; elsewhere the walls are in contact, except during deglutition, when they are opened by the tensor and levator veli palatini muscles. The mucosa of the osseous part is thin, and firmly attached to the bony wall, but in the cartilaginous part it becomes thicker, looser, and folded, and contains mucous glands, especially near the pharynx, where there is also some adenoid tissue.

The development of the external and middle ear.—Embryologically the external and middle ears have a common origin quite distinct from that which gives rise to the internal ear, and are to be regarded as portions of the branchial arch apparatus, secondarily adapted to auditory purposes. They are formed from the upper part of the first branchial cleft (see p. 9), and the adjacent portions of the first and second branchial arches.

The branchial cleft is represented in the human embryo by an external and a corresponding internal or pharyngeal groove, separated by a thin membrane, there being no formation of an actual cleft. The lower portion of the **external groove** closes, while the upper part persists as the external acoustic meatus, the auricle being formed from the adjacent portions of the first and second branchial arches. The first arch gives rise to the tragus, and the crus and upper portion of the helix, and the second arch to the remainder of the helix, the anthelix, antitragus, and lobule.

The **membrane** forming the floor of the groove and separating it from the pharyngeal groove becomes the tympanic membrane, which is thus lined on its outer surface by ectoderm and on its inner by endoderm. The lips of the upper part of the **pharyngeal groove** unite, so that the portion of the groove is converted into a cavity, from which are formed the tympanic cavity and the tuba auditiva (Eustachian tube); the lower portion of the groove remains open and is represented in the adult by the fossa in which the tonsil lies, and by the supratonsillar fossa. The auditory ossicles and their muscles are derived from the neighbouring arches, the malleus and incus, together with the tensor tympani, being derived from the first arch, while the stapes and stapedius come from the second.

The tympanic cavity is at first quite small, but later increases greatly, partly by the condensation of the loose areolar tissue which underlies its mucous membrane, the auditory ossicles and their muscles being thus apparently brought within the cavity, and partly by the absorption of the neighbouring bone. By this latter process the antrum and the tympanic and mastoid cells are formed, all these depressions or cavities being lined by mucous membrane continuous with that of the tympanic cavity.

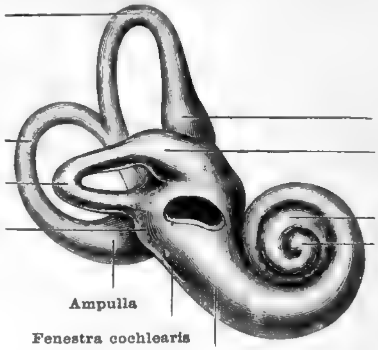
THE INTERNAL EAR

The **internal ear** is the essential part of the organ of hearing. It consists of a cavity, the osseous labyrinth, contained within the petrous portion of the temporal bone, and enclosing a membranous labyrinth. The **osseous labyrinth** is divided into **cochlea, vestibule,** and **semicircular canals,** which have been described on pages 69 to 71.

The **membranous labyrinth,** in which the acoustic nerve ends, lies within the osseous labyrinth, the form of which it more or less closely resembles. It is much smaller in diameter than the osseous, and its delicate walls are separated from the bone by an endothelial-lined space which is filled with a fluid, the **perilymph,** while the fluid which it itself contains is termed the **endolymph.** The portion of the membranous labyrinth situated in the vestibule consists of two sacs, the utricle and saccule (figs. 755, 756, 757). The **utricle** is an oval tubular sac, whose rounded end lies in the superior and dorsal portion of the vestibule. It is here tightly bound to the elliptic recess (fovea hemielliptica) by connective tissue and by the entrance of the filaments of the utricular division of the acoustic nerve as they pass from the superior macula cribrosa to the wall of the utricle. In the anterior part of the interior of the utricle, an

oval, whitish, thickened area, **macula acustica utriculi,** marks the terminal distribution of the nerve, and posteriorly the utricle is joined by the orifices of the semicircular canals. The **saccule** is a flattened, oval sac, smaller than the utricle, and situated in the anterior and inferior part of the vestibule. It is bound to the spherical recess (fovea

FIG. 752.—THE OSSEOUS LABYRINTH OF THE RIGHT SIDE. (Modified from Soemmerring. Enlarged.)

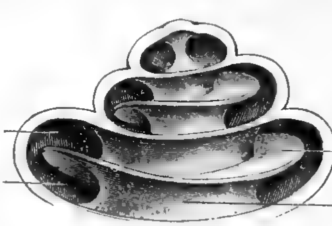


hemisphærica) by connective tissue and by the saccular division of the acoustic nerve, filaments of which extend from the middle macula cribrosa to the anterior and medial wall of the saccule, to be distributed over a thickened area, **macula acustica sac-**

FIG. 753.—INTERIOR OF THE OSSEOUS LABYRINTH OF THE LEFT SIDE. (Modified from Soemmerring. Enlarged.)

culi. Anteriorly and inferiorly the saccule gradually passes into a short canal, the **ductus reuniens,** which connects it with the cochlear duct, and posteriorly the very small **endolymphatic duct** is attached. This extends through the aquæductus ves-

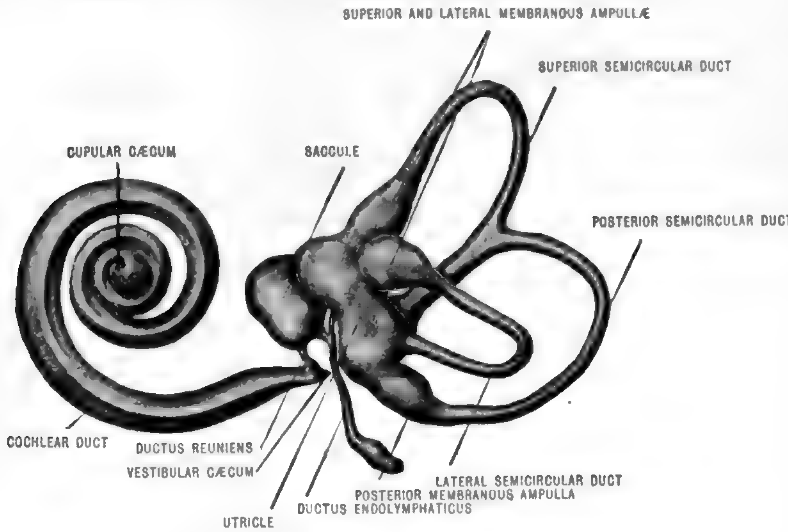
FIG. 754.—INTERIOR OF THE OSSEOUS COCHLEA. (Enlarged.)



tibuli to the posterior surface of the petrous portion of the temporal bone, where it ends in a dilated blind pouch, the **endolymphatic sac,** situated just beneath the dura. Just beyond the saccule the endolymphatic duct is joined at an acute angle by a short canal of minute calibre, the **utriculo-saccular duct,** which opens into the utricle

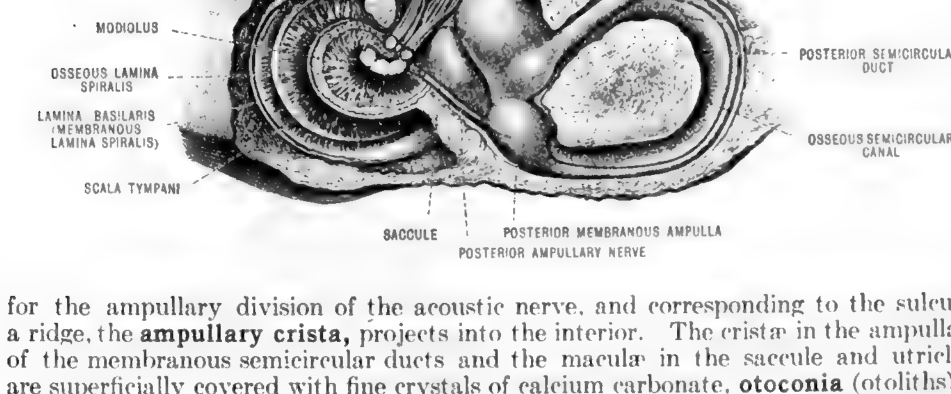
through its anterior medial wall and, with the endolymphatic duct, connects it with the saccule. The **semicircular ducts** (membranous semicircular canals) are situated within the osseous semicircular canals and are, therefore, known as the lateral, superior, and posterior semicircular ducts. They connect with the utricle by five openings, the posterior and superior ducts uniting to form a common crus before

Fig. 755.—Diagram of the Left Membranous Labyrinth. (Deaver.)



their termination. Each duct is less than a third of the diameter of the bony canal, from which it is separated by a large **perilymphatic space,** except along the greater curvature, where it is attached. The ducts are dilated in the bony ampullæ, producing the **lateral, superior,** and **posterior membranous ampullæ,** and on the attached surface of each of these there is a transverse groove, the **ampullary sulcus,**

Fig. 756.—Right Membranous Labyrinth of a Newborn Child. Exposed by Partial Removal of the Bony Labyrinth. Dorsal view. (Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)

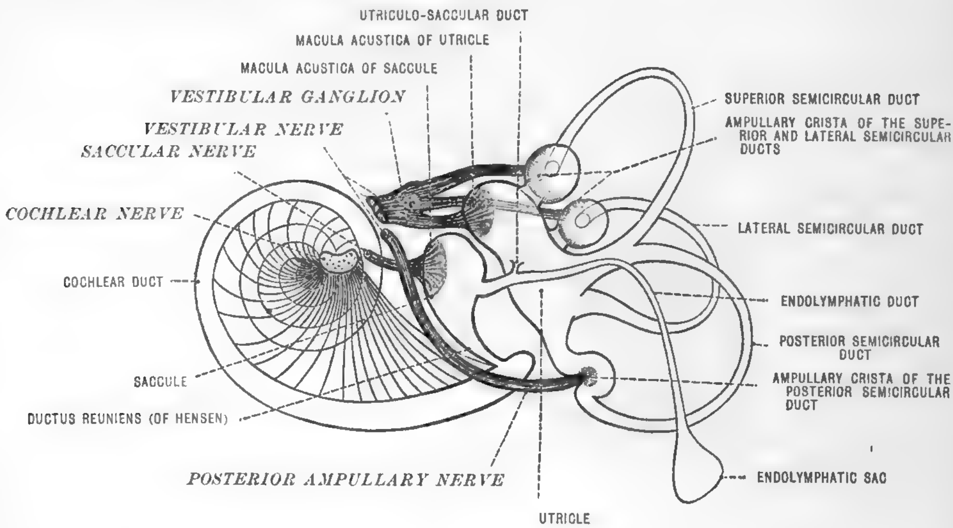


for the ampullary division of the acoustic nerve, and corresponding to the sulcus a ridge, the **ampullary crista,** projects into the interior. The cristæ in the ampullæ of the membranous semicircular ducts and the maculæ in the saccule and utricle are superficially covered with fine crystals of calcium carbonate, **otoconia** (otoliths).

The **cochlear duct** (membranous cochlea or scala media) begins within the

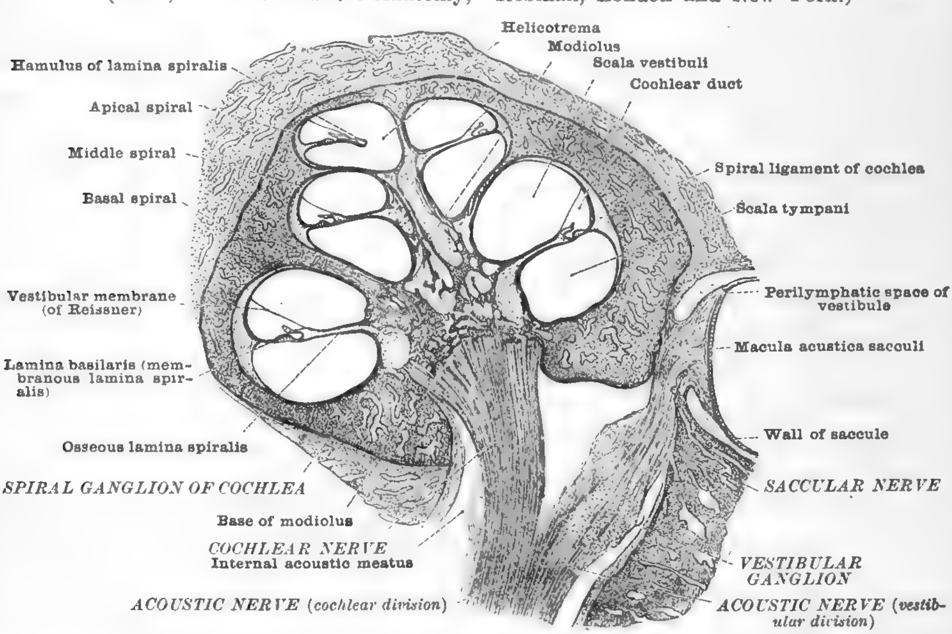
cochlear recess of the vestibule in a blind pouch, the **vestibular cæcum,** and traversing the spiral canal of the cochlea, ends just beyond the hamulus of the lamina spiralis in a second blind pouch, the **cupular cæcum.** Close to the vestibular cæcum

FIG. 757.—SCHEMATIC REPRESENTATION OF THE RIGHT MEMBRANOUS LABYRINTH AND THE DIVISIONS OF THE ACOUSTIC NERVE. Dorsal view. (Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



it is joined to the saccule by the **ductus reuniens.** It is lined throughout by epithelium and is somewhat triangular in cross-section. Its floor is formed by thickened periosteum over part of the osseous lamina spiralis and by a fibrous membrane, the

FIG. 758.—AXIAL SECTION THROUGH THE DECALCIFIED COCHLEA OF A NEWBORN CHILD. (Toldt, "Atlas of Human Anatomy," Rebman, London and New York.)



lamina basilaris, which stretches from the free border of the lamina spiralis to a thickening of the periosteum, the **spiral ligament** of the cochlea, on the peripheral wall. The epithelium of this floor is greatly modified, forming the **spiral organ**

(organ of Corti), in which the fibres of the cochlear nerve terminate. The peripheral wall is formed by the thickened periosteum upon the peripheral wall of the cochlear canal, while the third wall is formed by a thin **vestibular membrane (membrane of Reissner)** which passes from the peripheral wall to the osseous lamina spiralis near its free margin, forming with the lamina spiralis an angle of 45 degrees. The cochlear duct and the osseous spiral lamina divide the cochlear spiral canal into two parts, one next to the basilar membrane, the **scala tympani,** and one next to the vestibular membrane, the **scala vestibuli.** The scala tympani unites with the scala vestibuli at the helicotrema, and from the scala tympani a minute canal, the **perilymphatic duct,** passes through the cochlear canaliculus and connects with the subarachnoid space. A thin fibrous layer, the **secondary tympanic membrane,** closes the cochlear fenestra (fenestra rotunda) and thus separates the scala tympani from the tympanic cavity, and the vestibular perilymphatic space (scala vestibuli) is separated from the tympanic cavity by the base of the stapes in the vestibular fenestra (fenestra ovalis).

Vessels and nerves.—The internal auditory artery (p. 546, fig. 477), a branch of the basilar, accompanies the acoustic nerve. It supplies the vestibule, semicircular canals, and cochlea, and their membranous contents. The blood is returned by the internal auditory vein into the inferior petrosal sinus, and by small veins which pass through the cochlear and vestibular aqueducts to the inferior and superior petrosal sinuses. **The acoustic nerve** (p. 979, figs. 583 and 758) consists of a vestibular and a cochlear division. The membranous ampullæ of the semicircular ducts and the acoustic maculæ of the utricle and saccule are supplied by the vestibular nerve. The spiral organ (organ of Corti) in the cochlear duct is supplied by the cochlear nerve.

The development of the internal ear.—The internal ear is the essential organ of hearing, and appears at an early stage in the embryo as a depression of the ectoderm at the side of the head, above the dorsal end of the second branchial arch. The depression is lined by a thickened epithelium, and, sinking more deeply into the subjacent mesodermic tissue, is eventually constricted from the ectoderm to form a rounded sac, the **otocyst,** imbedded in the mesodermic tissue which will become the petrous portion of the temporal bone. From this simple ectodermic sac the entire membranous internal ear is formed, the so-called osseous internal ear being merely the bony walls of the cavity in which the otocyst lies.

THE TONGUE

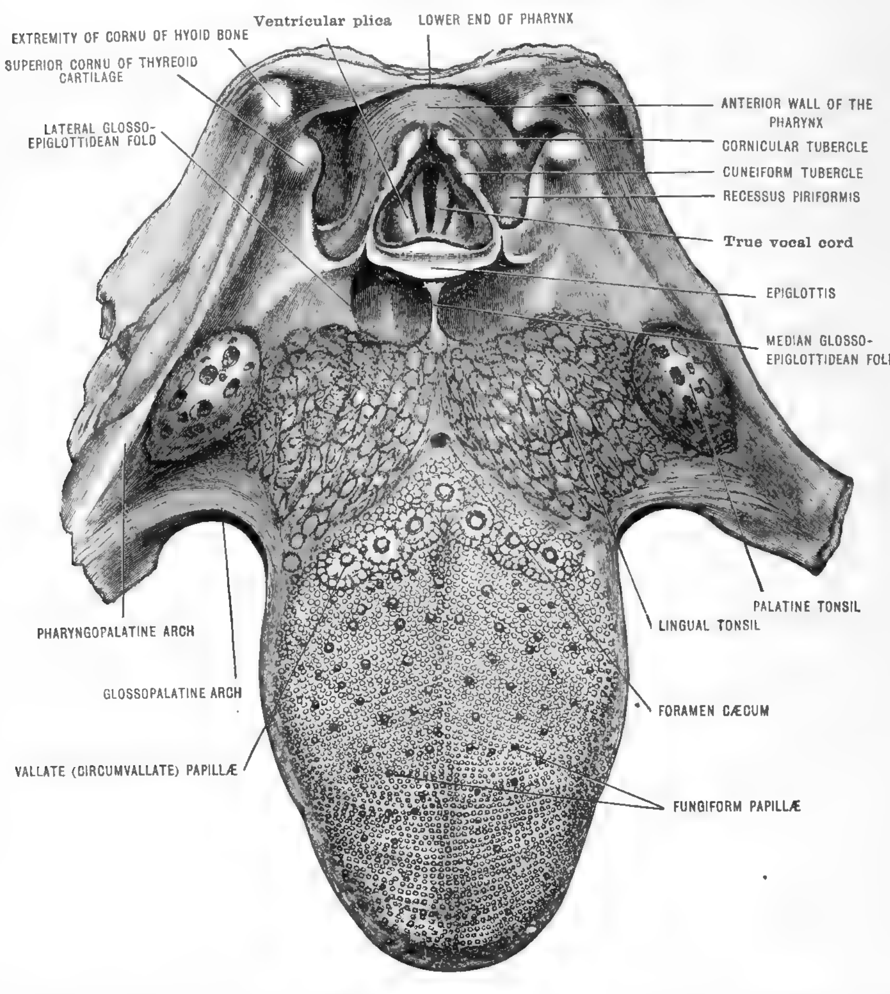
ORIGINALLY WRITTEN BY ARTHUR HENSMAN, F.R.C.S.; REVISED FOR SECOND AND THIRD EDITIONS BY ARTHUR ROBINSON, M.D., F.R.C.S.; REVISED AND LARGELY REWRITTEN FOR FOURTH EDITION

BY ABRAM T. KERR, B.S., M.D.

PROFESSOR OF ANATOMY IN THE CORNELL UNIVERSITY MEDICAL COLLEGE

The **tongue** is a muscular organ covered with epithelium. It is highly sensitive and freely movable, and plays an important part in the mastication and deglutition

FIG. 759.—DORSUM OF THE TONGUE.



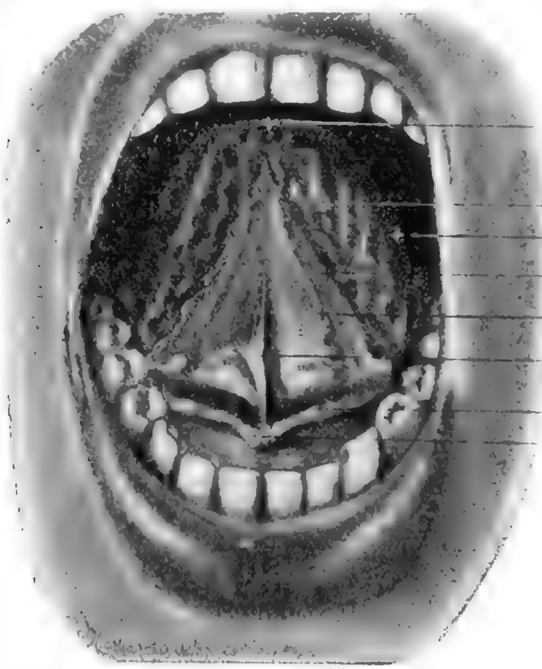
of the food, and is one of the organs of speech. Moreover, it is the principal seat of the organ of taste. It has the following parts: a superior surface, the **dorsum,** sepa-

rated in its anterior two-thirds from the **inferior surface** by the **lateral margins and apex.** A muscular **body** is attached posteriorly and inferiorly at the **root.**

The **dorsum** (fig. 759) is marked in its anterior two-thirds by a slight longitudinal groove, the **median sulcus,** and just beyond the dorsal end of this there is usually a small blind pouch, the **foramen cæcum** (Morgagni), which represents the superior end of the thyreo-glossal duct. Two slight grooves run ventrally and laterally from the foramen cæcum, and together form a V-shaped groove, the **terminal sulcus,** which marks the point of union of the body of the tongue, derived from the tuberculum impar, and the root, derived from the anterior ends of the second and third branchial arches. It also marks a division of the dorsum into a ventral or oral portion and a dorsal or pharyngeal part.

The **mucous membrane** covers the whole of the free surface of the tongue (fig. 759). Dorsally, in the middle line, is the prominent **median glosso-epiglottic fold,** and on each side of this the more rounded **lateral glosso-epiglottic folds,** connecting the tongue and the epiglottis. Between the median and lateral fold on each side there is a shallow fossa, the **epiglottic vallecula.** Laterally the mucous

Fig. 760.—Superior Surface of the Tongue. (Modified from Spalteholz.)



membrane of the dorsal portion is reflected over the tonsil and palatine arches, and ventrally it is reflected over the lateral margins and apex to the inferior surface, from which it passes to the floor of the mouth and thence to the gums of the lower jaw.

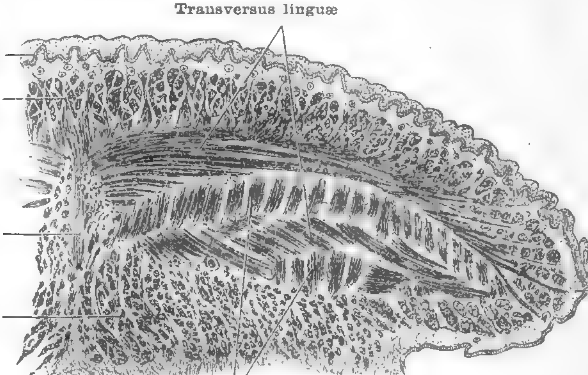
Upon the inferior surface of the tongue, near the tip, is a median depression (fig. 760), from which a prominent median fold of mucous membrane, the **frenulum,** stretches to the gums. On each side of the frenulum, and close to it, at about the junction of the inferior surface of the tongue and the floor of the mouth, is a rounded nodule, the **sublingual caruncle,** upon which the submaxillary duct opens. Running dorsally and laterally from each caruncle is a long, rounded ridge, the **sublingual fold,** beneath which is situated the sublingual gland, and about midway between the frenulum and the lateral margins of the tongue are two ragged folds of mucous membrane, the **fimbriate folds,** which converge ventrally. Between these folds and the frenulum the ranine veins are seen beneath the mucous membrane.

Papillæ of the tongue.—Over the oral portion of the dorsum of the tongue the red mucous membrane is somewhat whitened by the thickening of the epithelium, which produces the numerous **lingual papillæ** (fig. 759). Four kinds can be dis-

tinguished. The **filiform papillæ** are the smallest and most numerous, and are filiform or conical in shape and thickly cover the ventral two-thirds of the dorsum and also the lateral margins and apex. They are arranged in faintly marked lines which are parallel posteriorly with the terminal sulcus, but become more transverse towards the tip. They are best developed dorsally in the middle line, and those which are largest and longest are known as the **conical papillæ.** The **fungiform papillæ** are scattered irregularly among the preceding over the dorsum, lateral margins, and apex of the tongue, being most numerous in the two latter situations. The epithelium covering them is thinner than in the filiform papillæ, and they are, therefore, redder in colour. Each consists of a comparatively narrow base supporting a broader, rounded, free extremity. Many on the margins are flattened or lens shaped, and are called **lenticular papillæ.** The **vallate (circumvallate) papillæ,** seven to twelve in number, are the largest. They are arranged in a V-shaped line ventral to the terminal sulcus and parallel with it. Each presents an attached base slightly narrower than the broad, flattened, free top, and is situated in a circular depressed fossa surrounded by a slight ridge, so that the top of the papilla and the ridge project but slightly above the surrounding surface. In the fossa one or more serous glands open. The **foliate papillæ** are represented by six or seven vertical folds of mucous membrane separated by grooves. They are situated upon the lateral margin of the tongue just ventral

FIG. 761.—TRANSVERSE SECTION THROUGH THE LEFT HALF OF THE TONGUE. (Magnified.)

(From a preparation by Mr. J. Pollard, Middlesex Hospital Museum.)



to the glosso-palatine arch, and are more or less rudimentary in man, compared with their development in some of the lower mammals.

The **gustatory organ** is formed by microscopic special end-organs of taste, the **caliculi gustatoria** or **taste-buds,** which, besides being found upon the epiglottis and velum palatinum (soft palate), are located on the vallate, fungiform, lenticular, and foliate papillæ, but are absent from the filiform and conical.

Beneath the mucous membrane of the posterior third of the tongue abundant lymphoid tissue is collected to form nodular masses of variable size, the **lingual follicles,** which are grouped together under the name of the **lingual tonsil.** They extend from the terminal sulcus to the epiglottis, and laterally as far as the palatine tonsils. The **lingual glands** which lie beneath the mucous membrane of the lingual tonsil are especially abundant near the foramen cæcum and around the vallate and foliate papillæ. A special group forms on each side of the frenulum, and just medial to the tip of the tongue, an oval mass, the **anterior lingual glands** (glands of Nuhn or Blandin), which are partially covered by muscular fibres.

Muscles of the tongue.—A layer of fibrous connective tissue, the **lingual septum,** separates the halves of the tongue, extending in the median plane from the apex to the base, where it is attached to the hyoid bone. The muscles of the tongue are classified as extrinsic and intrinsic. The **extrinsic muscles** are the hyo-glossus, genio-glossus, stylo-glossus, and glosso-palatinus (palato-glossus), and part of the

FIG. 762.—LEFT SIDE OF THE TONGUE, WITH ITS MUSCLES.

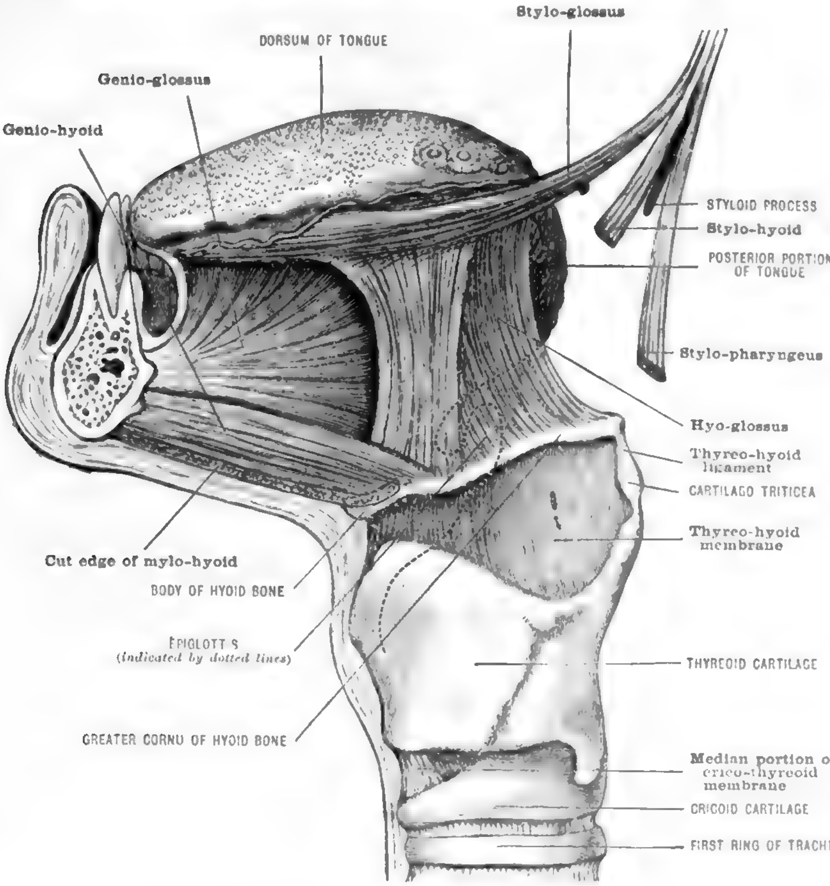
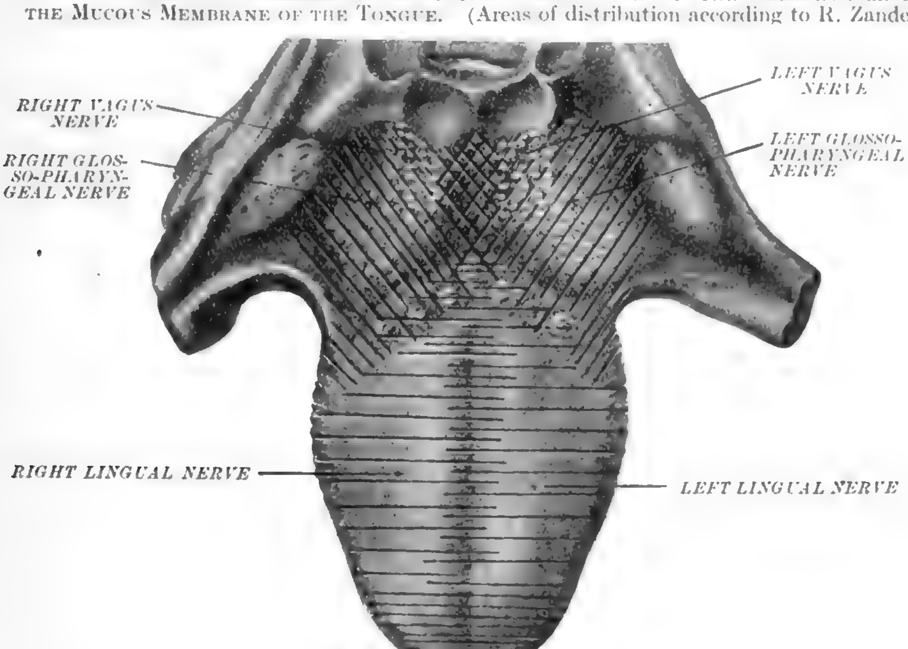


FIG. 763.—SCHEMATIC REPRESENTATION OF THE DISTRIBUTION OF THE SENSORY NERVES IN THE MUCOUS MEMBRANE OF THE TONGUE. (Areas of distribution according to R. Zander.)



superior constrictor of the pharynx, all of which are described elsewhere (see pp. 344, 1078, and 1085).

The intrinsic muscles.—The **longitudinalis superior** (fig. 761) is a superficial longitudinal stratum extending from the base to the apex of the tongue, immediately beneath the mucosa of the dorsum, to which many of its fibres are attached. The **longitudinalis inferior** (fig. 761) is composed of two muscle-bands extending from base to apex on the inferior surface of the tongue, and is situated between the hyoglossus and the genio-glossus, some of its fibres near the apex mixing with the styloglossus, while dorsally some are attached to the hyoid bone. The **transversus linguæ** (fig. 761) consists of fibres which pass transversely, and is situated between the superior and inferior longitudinal muscles. The fibres arise from, or pass through, the septum linguæ, and are attached to the mucosa of the dorsum and lateral margins of the tongue. The **verticalis linguæ** (fig. 761) is composed of fibres which pass from the mucosa of the dorsum to the mucosa of the inferior surface of the tongue, interlacing with those of the other intrinsic and extrinsic muscles.

Vessels and nerves.—The **lingual arteries** furnish the principal blood-supply (p. 520, fig. 410). The **lingual veins** (p. 664) carry the blood from the tongue to the internal jugular. The **lymphatics** from the ventral portion empty into the submaxillary lymph-nodes and from the posterior portion into the deep cervical nodes. **The nerves** are motor and sensory (fig. 763). The **hypoglossal nerve** supplies the intrinsic and all the extrinsic muscles of the tongue except the glosso-palatinus (palato-glossus), which is supplied from the pharyngeal plexus (p. 984). The sensory nerves are:—the **lingual nerve,** a branch of the mandibular division of the fifth, which, after joining with the chorda tympani from the seventh, is distributed to the anterior two-thirds of the tongue (p. 969); the **lingual branches of the glosso-pharyngeal,** which are distributed to the pharyngeal third of the tongue, including the vallate papillæ (p. 981); and **the superior laryngeal branch of the vagus,** which supplies a small area near the epiglottis.

The development of the tongue.—The tongue arises from two distinct origins, one of which is paired. The anterior unpaired portion appears as a thickening in the floor of the mouth opposite the ventral ends of the first branchial arches, while the posterior paired portions are formed from a thickening over the ventral end of the second branchial arch of each side. The anterior portion is received posteriorly between the diverging limbs of the posterior portion, and a fusion of both portions occurs along a V-shaped line, situated immediately behind the line of the vallate papillæ, its apex being indicated by the foramen cæcum.

THE NOSE

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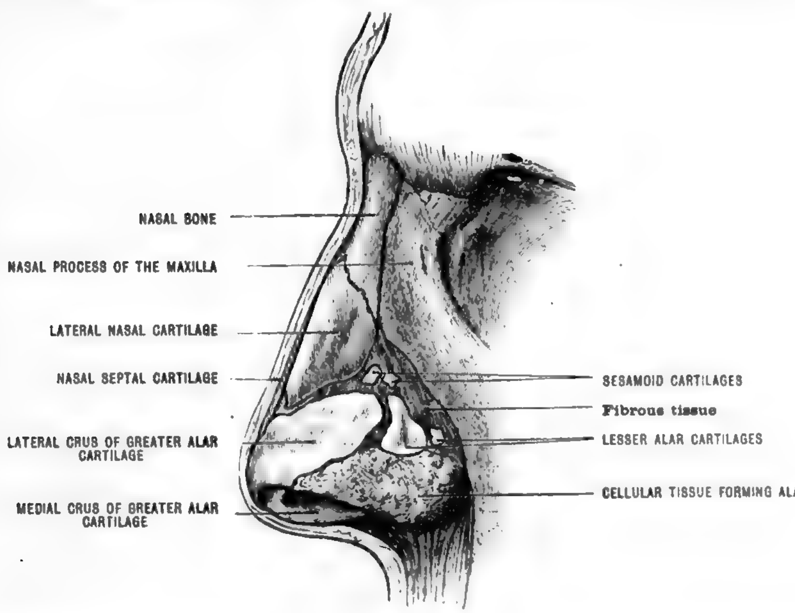
BY ABRAM T. KERR, B.S., M.D.,

PROFESSOR OF ANATOMY IN THE CORNELL UNIVERSITY MEDICAL COLLEGE

The **nose** contains the organ of smell and serves also as one of the organs of respiration. It consists of the external nose, the nasal cavity, and the paranasal sinuses (accessory cavities).

The **external nose** (fig. 764) is shaped like a triangular pyramid. At the fore-

FIG. 764.—THE LEFT SIDE OF THE EXTERNAL NOSE, SHOWING ITS CARTILAGES, ETC.



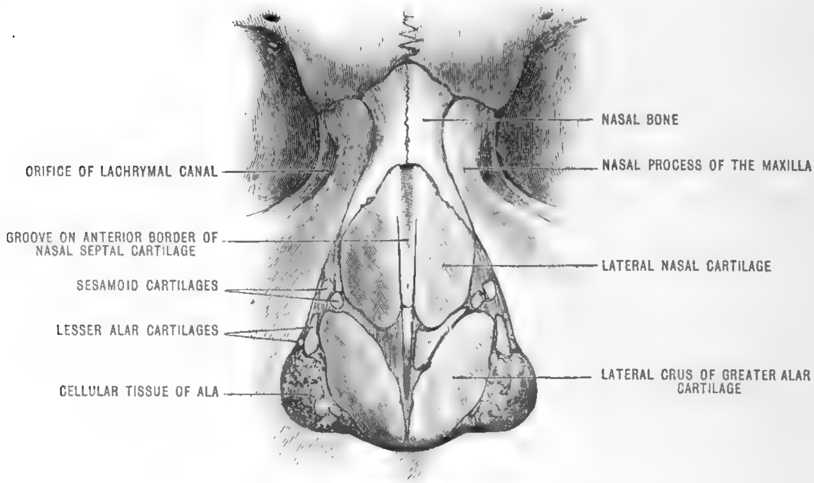
head, between the eyes, is the **root** of the nose, and from this, extending inferiorly and ventrally, is a rounded ventral border, the **dorsum** of the nose, which may be either straight, convex, or concave, and which ends inferiorly at the **apex** or tip. The superior part of the dorsum is known as the bridge. Inferiorly, overhanging the upper lip, is the **base** of the nose, which presents two orifices, the **nares** or nostrils, separated from one another by the inferior movable part of the nasal septum. The sides of the nose slope from the dorsum laterally and dorsally, and inferiorly are expanded and more convex, forming the **alæ nasi.** Each of these is separated from the rest of the lateral surface by a sulcus, and the inferior free border of each bounds a naris laterally.

The framework of the external nose is formed partly of bone and partly of hyaline cartilage. The bones, which form only the smaller superior part, are the two nasal

bones and the frontal processes and anterior nasal spines of the two maxillæ (pp. 76–80).

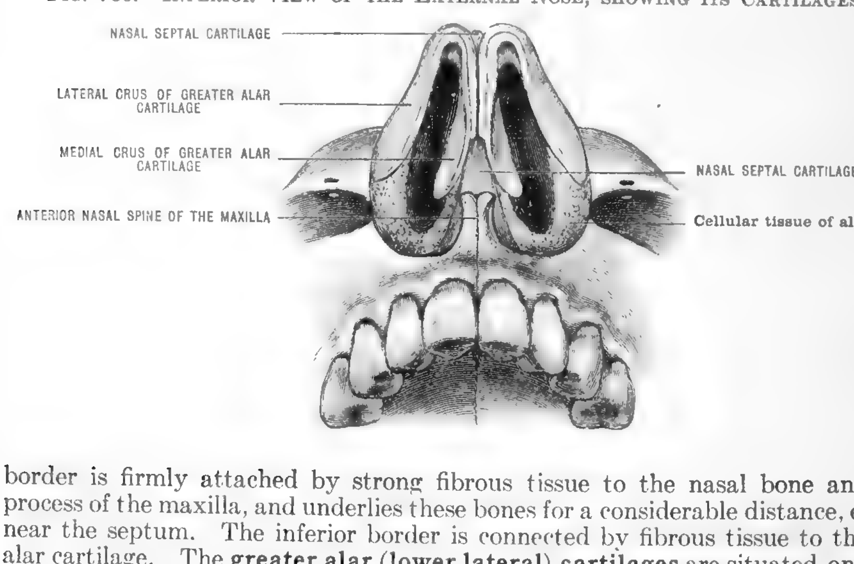
The nasal cartilages.—There are five principal cartilages: superiorly, the two *lateral nasal cartilages,* inferiorly the two *greater alar (lower lateral) cartilages,* and the single median *nasal septal cartilage.* Besides these there are the *lesser alar cartilages,* the *sesamoid cartilages,* and the *vomero-nasal cartilages* of Jacobson. The

FIG. 765.—VENTRAL VIEW OF THE EXTERNAL NOSE, SHOWING ITS CARTILAGES, ETC.



lateral nasal cartilages are triangular and nearly flat lateral expansions of the septal cartilage, placed one on each side of the nose just inferior to the nasal bone. Each presents an inner and an outer surface and three borders. The medial border is continuous in its superior third with the ventro-superior margin of the septal cartilage, and through this with its fellow of the opposite side, but it is separated inferiorly from the septal cartilage by a narrow cleft. The curved dorso-lateral

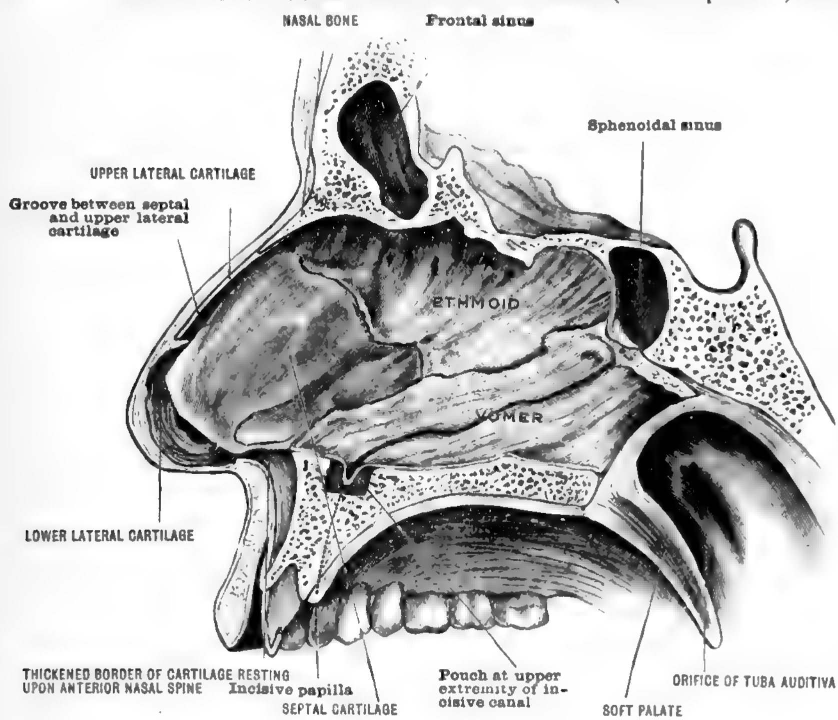
FIG. 766.—INFERIOR VIEW OF THE EXTERNAL NOSE, SHOWING ITS CARTILAGES, ETC.



border is firmly attached by strong fibrous tissue to the nasal bone and frontal process of the maxilla, and underlies these bones for a considerable distance, especially near the septum. The inferior border is connected by fibrous tissue to the greater alar cartilage. The **greater alar (lower lateral) cartilages** are situated one on each side of the tip of the nose (figs. 764, 766). Each is thin, pliant, curved, and so folded that it forms a medial and a lateral crus, which bound and tend to hold open each naris. The *medial crus* is loosely attached to its fellow of the opposite side, the two being

situated inferior to the septal cartilage and forming the tip of the nose and the ventral part of the mobile septum. The *lateral crus* joins the medial crus at the apex of the nose; it is somewhat oval in shape, and curves dorsally in the superior and ventral portion of the ala. It is connected posteriorly to the nasal margin of the maxilla by a dense mass of fibrous and fatty tissue, and helps to maintain the contour of this part of the nose. A variable number of small cartilages, **lesser alar (sesamoid) cartilages,** are found in this fibrous tissue of the ala, and the interval between each greater alar and lateral cartilage is more or less completely filled by one or more small plates, **sesamoid cartilages** (fig. 764). The **septal cartilage** (fig. 767) fits into the triangular interval of the bony septum. Its *ventro-superior border* is attached to the dorsal border of the internasal suture. Inferior to the nasal bone it presents a shallow groove which gradually narrows towards the tip of the nose, and whose borders are continuous superiorly with the lateral nasal cartilages, but are separated from their inferior two-thirds by a narrow slit. The most inferior part

Fig. 767.—Medial Wall of the Nasal Cavity, the Mucous Membrane Being Removed. The dotted line indicates the course of the incisive (anterior palatine) canal.



of this border of the septal cartilage is placed between the greater alar cartilages. The *ventro-inferior border* extends dorsally from the rounded ventral angle to the anterior nasal spine. Inferiorly it is attached to the medial crus of the greater alar cartilage and to the mobile nasal septum. The *dorso-superior border* is attached to the perpendicular plate of the ethmoid, and the *dorso-inferior border* joins the vomer and the ventral part of the nasal crest of the maxilla, the cartilage broadening out to obtain a wide though lax attachment to the nasal spine. The shape of the septal cartilage varies with the extent of the ossification of the bony septum. Even in the adult a strip of cartilage may extend for a varying distance dorso-superiorly between the vomer and perpendicular plate of the ethmoid, sometimes reaching the body of the sphenoid and being known as the *sphenoidal process* of the septal cartilage. The **vomero-nasal cartilage** is a narrow strip of cartilage firmly attached to each side of the septal cartilage, where this joins the ventral portion of the vomer.

The nasal septum is almost always straight in children and aboriginal skulls; but in a large proportion of adults it is deflected to one side or the other.

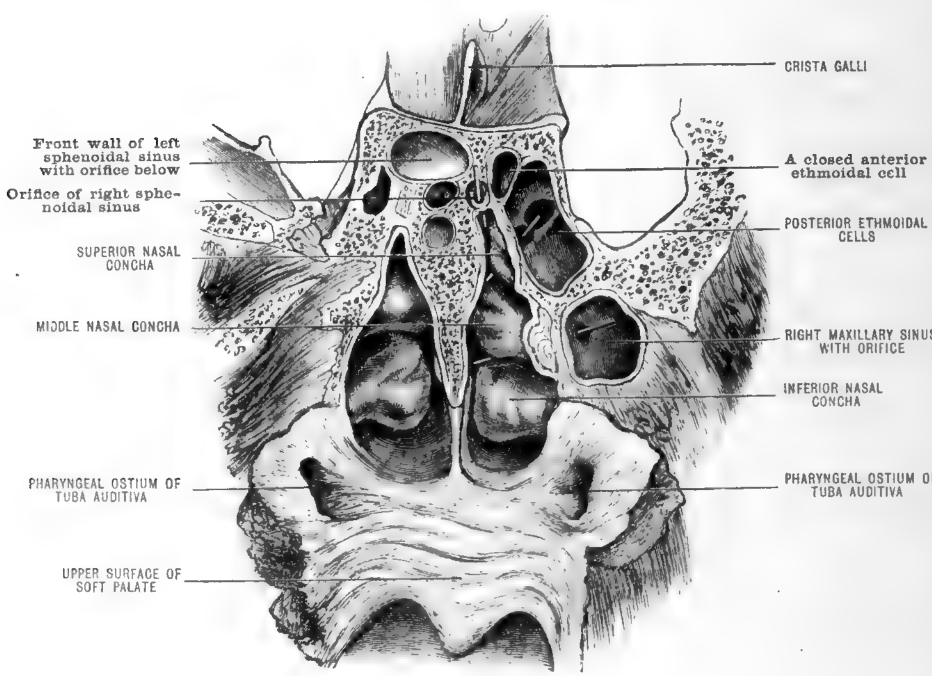
Muscles.—The muscles are grouped as dilators and constrictors, the latter being comparatively feeble in their action. They are described on pp. 330 and 331.

The **skin** covering the external nose is thin and freely movable upon the subjacent parts, except at the tip and over the cartilages, where it is much thicker, more adherent, and furnished with numerous large sebaceous glands. At the nares it is reflected into the nasal cavity as far as the limen, where it joins the mucous membrane. The hairs on the skin of the nose are very fine, except in the nares, where they may be strongly developed, and are then known as **vibrissæ.**

Vessels and nerves.—The **arteries** of the external nose are derived from the external maxillary (facial) artery (pp. 523 and 524), the ophthalmic artery (p. 538), and the infra-orbital artery (p. 531). The **veins** terminate in the facial vein and the ophthalmic vein (p. 662). The **lymphatics** pass to the submaxillary lymphatic nodes (p. 708). The **motor nerves** are branches of the facial (p. 979). The **sensory nerves** are derived from the fifth through the frontal and naso-ciliary branches of the ophthalmic (p. 966) and infra-orbital branch of the maxillary (p. 968).

The **nasal cavity** is composed of the two nasal fossæ, the bony walls of which have already been described (pp. 101–104). The **nasal fossæ** extend from the ventral

Fig. 786.—Oblique Section passing through the Nasal Fossæ just in Front of the Choanæ. (Seen from behind.)



opening upon the face, the nares, to the dorsal communication with the pharynx, the **choanæ** or posterior nares. Each fossa has a roof, a floor, a lateral and medial wall.

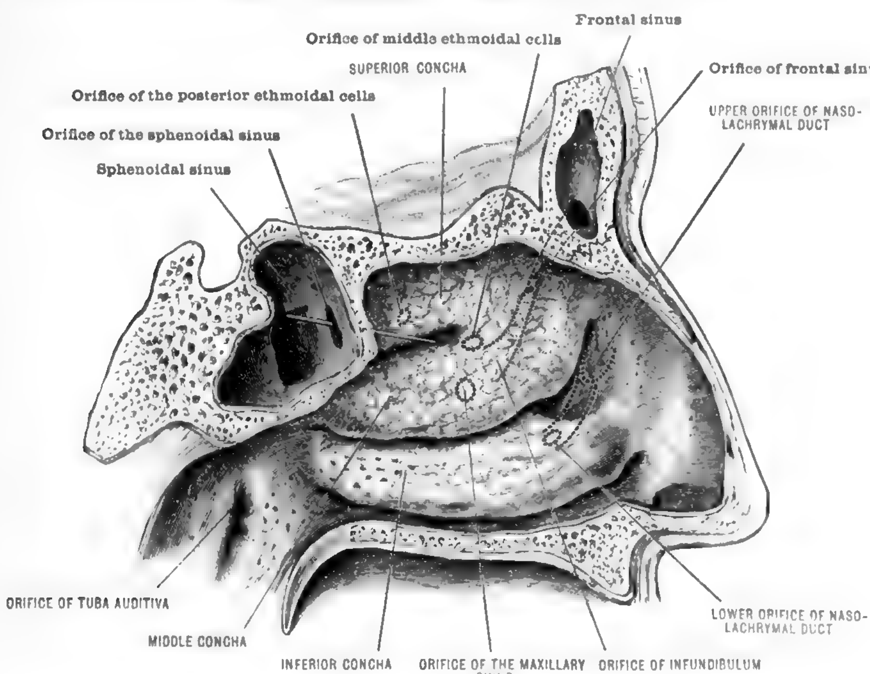
The **medial wall** (fig. 767) separates the two fossæ. Its framework is formed by the vertical median **nasal septum,** which is composed of the *osseous septum* superiorly, the *cartilaginous septum* intermediately, and of the *membranous* or *mobile septum* inferiorly. As already noted, the septum is usually deflected to one side or the other. In the septum, upon each side, just superior to the nasal spines of the maxillæ, there is frequently a minute opening leading superiorly and dorsally and ending in a blind pouch. This cavity is closely related to the vomero-nasal cartilage and is a rudimentary representative of the *vomero-nasal organ* (*organ of Jacobson*), which in some animals is well developed and receives a branch of the olfactory nerve. Inferior and dorsal to its opening another small opening is often seen on the floor of the nasal fossa. This is the mouth of the *incisive duct*, which leads into the incisive canal for a greater or less distance and may even extend to the

mouth, where its termination is marked by the incisive papilla. The incisive duct indicates the position of the passage which originally connected the mouth and nose.

The **lateral wall** (fig. 769) presents just within the nares a slight depression, the **vestibule.** This corresponds to the expansion of the ala, and is marked off from the rest of the nasal fossa by a distinct ridge, the **limen nasi.** The area immediately superior and dorsal to the vestibule is separated into two shallow depressions by an oblique ridge, the **agger nasi,** the ventral depression being the **sulcus olfactorius** which leads to the olfactory region in the superior and dorsal part of the nasal fossa, while the area inferior and dorsal to the agger is the **atrium of the middle meatus.** This is bounded dorsally by the ventral vertical border of the middle nasal concha (middle turbinate bone), beneath which it is continued into the middle meatus. On the dorsal part of the lateral wall are the superior, middle, and inferior conchæ (turbinate bones), covering respectively the **superior, middle,** and **inferior meatuses.** The superior concha is occasionally divided into two or three parts, and posterior and superior to it is a depression, the **spheno-ethmoidal recess,** which leads to the opening into the sphenoidal sinus.

The **superior meatus** is the smallest of the three. It has but a single opening,

Fig. 769.—The Left Wall of the Nasal Cavity showing the Conchæ and Meatuses, with the Openings in Dotted Outline.



which leads into the posterior ethmoidal cells. The spheno-palatine foramen, which communicates with the meatus in the dry skull, is entirely covered up by mucous membrane.

The **middle meatus** is a much larger passage. Upon its lateral wall is a rounded eminence, the **ethmoidal bulla,** caused by the middle ethmoidal cells and perforated by the opening into them. Ventral and inferior to this is a deep curved groove, the **hiatus semilunaris,** which is continued superiorly by the **infundibulum** into the frontal sinus. It also receives the openings of the anterior ethmoidal cells and the **maxillary sinus (antrum).** Posterior to the semilunar hiatus an accessory opening into the maxillary sinus is often seen.

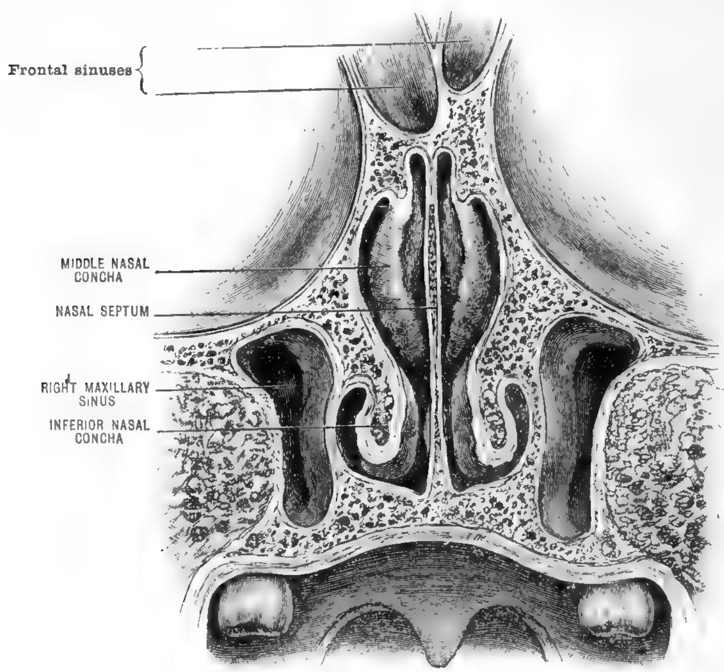
The **inferior meatus** is the longest of the three. Ventrally, just inferior to the attachment of the inferior concha (turbinate bone), is the slit-like opening of the **naso-lachrymal (nasal) duct,** around the opening of which the mucous membrane forms a valve, the **plica lachrymalis** (Hasneri).

The **common meatus** is the space between the nasal conchæ and the septum, and extends from the floor to the roof of the nasal fossa. The dorsal portion of the

nasal fossa, situated between the dorsal extremities of the middle and inferior conchæ (turbinate bones) and the anterior lip of the pharyngeal orifice of the tuba auditiva (Eustachian tube), is known as the **naso-pharyngeal meatus.**

The **nasal mucous membrane** (the pituitary or Schneiderian membrane).—The nasal cavity is completely lined with mucous membrane, which ventrally, at the limen, blends with the skin which lines this part of the vestibule (p. 1070). Dorsally it joins the mucous membrane of the pharynx and palate. It covers up some of the openings which are seen in the bony walls; those, however, which lead into the air-sinuses and into the naso-lachrymal duct remain patent, although the bony openings are much reduced in size. In the nasal cavity proper the bright rose-red vascular mucous membrane is tightly bound to the periosteum and perichondrium, and is covered with a ciliated columnar epithelium. Numerous large mucous **nasal glands** pour their more or less watery secretion over the entire surface, and form in the submucous stratum a layer of considerable thickness. Here, also, a very considerable venous plexus is found, especially over the middle and inferior conchæ (turbinate bones), where it forms the **cavernous plexus** of the conchæ. The thickness which these glands and venous plexuses give to the mucous membrane causes the air-spaces of the bony fossæ to be much contracted in the recent state, and in children a considerable amount of adenoid tissue is also found in the submucous layer. The region covered by the mucous membrane just described forms the greater part of the nasal cavity, and is known as the **respiratory region.** A small area of the mucous membrane over the superior concha and the adjacent septal wall (fig. 772) has a somewhat different structure. In this area the olfactory nerves terminate, whence it is known as the **olfactory region,** and its mucous membrane, compared with that of the respiratory region, is less vascular, yellow or yellowish-brown in colour, and covered by a non-ciliated epithelium. It contains specially modified cells, which form the true **olfactory organ** and receive the terminations of the olfactory nerve. Small mucous **olfactory glands** occur in the region. The **paranasal sinuses** or accessory cavities which connect with the nasal cavity are: the **maxillary sinuses** (antra of Highmore), the **sphenoidal sinuses,** the **frontal sinuses,** and the **ethmoidal cells,** and have been described in the section on OSTEOLOGY. The mucous membrane

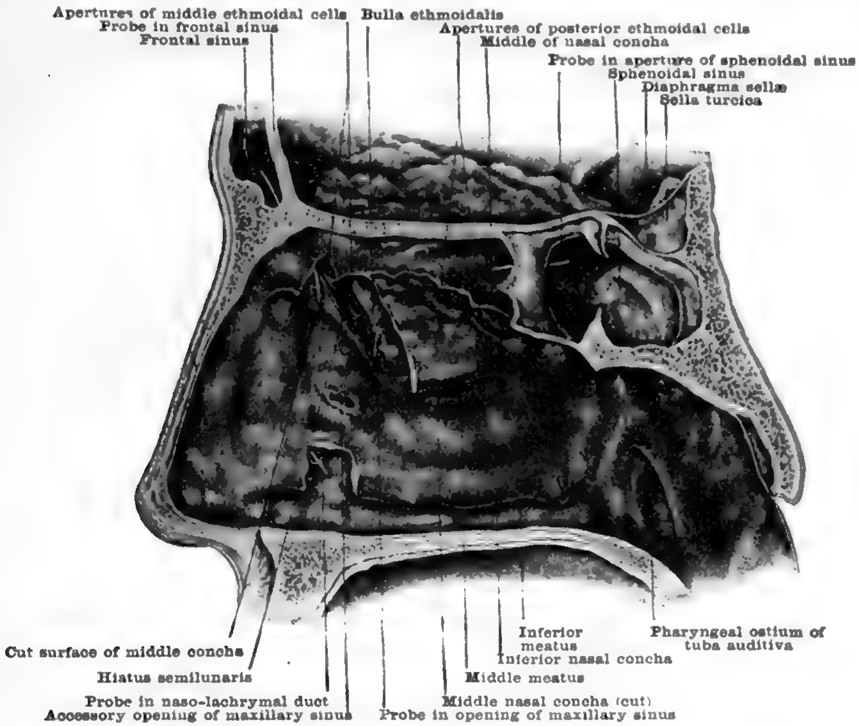
FIG. 770.—TRANSVERSE SECTION THROUGH THE NASAL FOSSÆ AND MAXILLARY SINUS AT THE DORSAL EXTREMITY OF THE MIDDLE CONCHA. (Ventral view.)



which lines the paranasal sinuses throughout is a continuation of the nasal mucosa; it is, however, paler, less vascular, somewhat thinner, and more loosely attached to the bones.

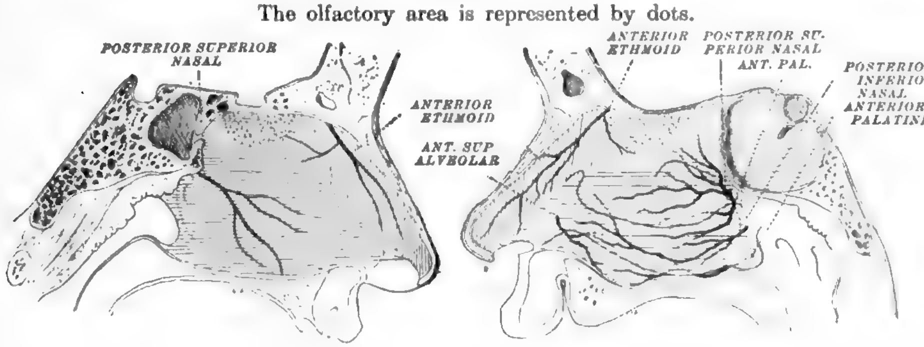
Vessels and nerves.—The **arteries** of each nasal fossa are the spheno-palatine artery from the internal maxillary (p. 532), the anterior and posterior ethmoidal arteries from the ophthalmic

FIG. 771.—LATERAL WALL OF THE NOSE, SHOWING ORIFICES OF ACCESSORY CAVITIES. (Deaver.)



(p. 537), and the descending palatine artery from the internal maxillary (p. 531). The **venous plexuses** of the mucous membrane are drained posteriorly by the spheno-palatine to join the pterygoid plexus, superiorly by the anterior and posterior ethmoidal veins to join the superior ophthalmic vein, and anteriorly by small branches to join the facial. The **lymphatics** form a well-developed plexus which communicates, through the lymphatics surrounding the olfactory nerves,

FIG. 772.—DIAGRAM OF THE DISTRIBUTION OF THE NERVES IN THE NASAL CAVITY. (Poirier and Charpy.)
The olfactory area is represented by dots.



with the subdural and subarachnoid space within the cranial cavity. Posteriorly two or more well-developed trunks communicate with the pharyngeal lymphatics, and anteriorly the nasal lymphatics join with the lymphatics of the face. The **olfactory nerves** pass through the cribriform plate of the ethmoid bone and are distributed to the olfactory area (p. 959). The **fifth cranial nerve** furnishes the following branches to each nasal fossa:—branches from the naso-ciliary

(nasal) branch of the ophthalmic nerve; the Vidian nerve; the posterior superior and posterior inferior nasal and the anterior palatine from the spheno-palatine ganglion (p. 972); the anterior superior alveolar from the infra-orbital division of the maxillary nerve (p. 968).

The development of the nose.—The nasal cavity makes its appearance as a depression of the ectoderm on either side of the median line, immediately in front of the oval fossa, with which the depressions are at first continuous. Later, by the union of the maxillary and globular processes (see p. 1076), the depressions are separated from the anterior part of the oral fossa, and this separation is continued by the formation of the palatal processes of the maxillæ and palatine bones, so that finally the nasal cavities communicate posteriorly only with the pharynx.

The cartilage which forms the lateral walls of the nasal fossæ is at first quite smooth, but later it becomes eroded by absorption, whereby the nasal conchæ are formed. The erosion also extends into the neighbouring bones, the frontal, sphenoidal, and maxillary sinuses, and the ethmoidal cells being formed in this manner, and being, accordingly, lined by mucous membrane continuous with that of the nasal cavities.

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